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ume 4 August 16, 1954 Number 3

E AND GROWTH STUDIES ON TWO SPECIES OF WHITEFISHES FROM POINT BARROW, ALASKA

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GROWTH PECULIARITIES OF THE CISCO, *COREGONUS SARDINELLA* (VALENCIENNES), IN THE VICINITY OF POINT BARROW, ALASKA

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AGE AND GROWTH STUDIES ON TWO SPECIES OF WHITEFISHES FROM POINT BARROW, ALASKA[1]

By Daniel M. Cohen

Introduction

The purpose of this study is to describe quantitatively age and growth characteristics of two species of whitefish found near Point Barrow, Alaska. These are the first age and growth studies of fresh-water species ever made in the Alaskan Arctic. They are a contribution towards a better understanding of the fishery resources of the area.

Before development and sound management of any fisheries resource is possible the dynamic inter-relationships of the fish populations involved must be understood. For a proper evaluation of population dynamics information must be available on the age composition of the population and the growth rates of the individuals.

Up to the present time, according to Wilimovsky (in press), utilization of Alaskan arctic fresh-water fishes by Eskimos has been inefficient and of secondary importance. The potentialities of these resources are unexplored, even though Eskimo fisheries have existed for a relatively long period of time.

Acknowledgments

The data for this paper were collected during the summer of 1952, while the author was acting as an assistant to Professor Donald E. Wohlschlag of Stanford University at the Arctic Research Laboratory, Point Barrow, Alaska. My most sincere thanks go to Professor Wohlschlag for his guidance and interest during the course of this study. I also wish to take this opportunity to acknowledge the assistance of Dr. Ira Wiggins, Director of the Arctic Research Laboratory, and the staff of the Laboratory during the summer of 1952. Dr. R. B. Miller of the University of Alberta was kind enough to check the readings on some difficult scales, and Mr. Norman J. Wilimovsky of Stanford University gave aid both in the field and through his knowledge of arctic fishes and fisheries. The paper was prepared in the Natural History Museum of Stanford University.

The Area

The fishes utilized in this study were collected from two locations near the Arctic Research Laboratory. *Coregonus sardinella* (Valenciennes)[2] and *Coregonus nasus kennicotti* Milner were taken from fresh-water Ikroavik Lake located approximately six miles south of the Arctic Research Laboratory. Ikroavik Lake is one of the shallow northern types discussed by Black and Barksdale (1949). Wohlschlag (1953) gives an excellent description of the lake and of the surrounding area.

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[1] This study is presented in partial fulfillment of Contract Nonr-225(08) with the Office of Naval Research.

[2] *Coregonus* must replace *Leucichthys* according to Legendre (1954) and Wilimovsky (1954).

A sample of *C. sardinella* was also collected from a body of water referred to by the Eskimos as the First Inlet. This inlet lies about three miles southeast of the Arctic Research Laboratory. It is a mile in length at most 350 yards wide. A sand spit curves across the mouth, and a narrow channel, 18 or 20 feet wide, connects the inlet to Elson Lagoon, a much larger body of water which is continuous with the Arctic Ocean. The five-foot-deep channel is the deepest part of the inlet and is scoured out by a tidal current which is present even in this area of small tide ranges. In spite of the fact that the salinity is relatively low (personal communication from Wilimovsky) the inlet might best be termed a brackish environment as indicated by the presence of marine forms such as the fishes *Myoxocephalus* and *Limanda*, the medusa *Chrysaora*, and euphausiids. Two-foot to three-foot tundra banks surround most of the inlet; however, at low tide a marginal mud flat area is exposed. Except for the channel near the mouth of the inlet the depth is three feet or less. The bottom is a sticky gray mud which extends several feet down to permafrost. The turbidity of the water usually limits visibility to a few inches; however, the water may be clearer near the mouth of the inlet during an ebb tide.

Methods

Fishes were captured in Ikroavik Lake and in the inlet by means of a 200-foot long seine, 15 feet deep in the middle and tapered to six feet at the ends. The seine was made of three-quarter inch (bar measure) mesh. In both locations a 100-by-six-foot gill net made of one inch (bar measure) mesh was also used. During the first week in September, two 250-by-six foot experimental gill nets were employed in Ikroavik Lake. Each was composed of 50-foot sections having three-quarter, one, one and one-quarter, one and one-half and two inch meshes.

Standard, fork, and total length measurements were made to the nearest millimeter.

Scales were taken from each fish from an area between the lateral line and the anterior edge of the dorsal fin. Van Oosten (1928) found that in *Coregonus artedi* the scales of this area were less variable with respect to size and shape than those found elsewhere on the body. The scales were placed in a scale book along with length and weight data and other pertinent observations. Each evening the scales collected during the day's observations were transferred to numbered scale envelopes, and the data and the number on the scale envelopes were entered in a notebook. The scales were later mounted in a glycerin and gelatin medium described by Lagler (1952). A projection machine consisting of a microscope, prism, mirror, and light source, magnified each scale 43 times for reading.

Age and Growth

Coregonus nasus kennicotti Milner

Spawning and Hatching period: According to Wynne-Edwards (1952) *Coregonus nasus kennicotti* Milner is found in the Mackenzie and in the Yukon rivers, and also has a Siberian distribution. As far as is known, no growth studies have even been carried out on this species.

Examination of the gonads of *kennicotti* during the course of the summer of 1952 indicated that the fish in Ikroavik Lake spawned during the month of July. In 1951, newly hatched fry were captured by Wilimovsky during the month of June, indicating an even earlier spawning period. Wynne-Edwards (1952) notes that *kennicotti* spawns in the rivers during the month of August.

The eggs take from 30 to 60 days to hatch rather than the 100 to 150 days more common in other coregonine fishes (Downing, 1904; Kiel, 1874; Bowers, 1900). The short hatching period may be due to the fact that the lake experiences its peak temperatures during the spawning and hatching period. Thus, in this shallow arctic lake, the early development of the fish takes place at temperatures ranging between 6° and 12° C. This is in contrast to the usual development which occurs at 4° C. in members of the genus which spawn later and dwell in deeper lakes farther to the south. In experimental work with *Coregonus clupeaformis* from Lake Erie, Price (1940) has shown that the incubation period could be speeded up by an increase in temperature. His findings seem to parallel closely the observed situation in Ikroavik Lake.

Because the Ikroavik Lake *C. n. kennicotti* spawns in the early summer and because the *C. sardinella* population in the lake spawns in September it would seem that the early spawning time of *kennicotti* in Ikroavik is an hereditary rather than an environmental phenomenon. Further investigations of other *kennicotti* populations in the immediate area might answer the question of whether or not this is merely an isolated instance of early spawning in one lake or a more widespread feature of the life history of this fish.

Although *kennicotti* in Ikroavik Lake hatch before the end of the growing season, it seems doubtful that they develop scales or an annulus during the summer of hatching. The newly hatched fish probably winter over with very little growth until the following June or July when the scales develop. An annulus would be formed with the interruption of growth during the second winter; however, the fish cannot be put into annulus class one (fish bearing scales with one complete annulus) until the resumption of growth the following spring. Thus, to obtain the true age of a fish, it is necessary to add one to the annulus class; that is, when scales are first laid down the fish is about one year old, and when one distinct annulus is present the fish is two years old. The age-annulus-year-spawned relationship is more fully illustrated in Table 1.

Age Frequency and Sex Ratio: The age-frequency data for *kennicotti* captured with all gear have been assembled in Table 1. Relative year-class abundance is highly irregular, and Point Barrow weather records for the years of spawning were examined in an attempt to explain the irregularities. However, no correlation was evident. Because of the small absolute size of the sample, and indeed of the entire population (Wohlschlag, 1953), chance fluctuations may be assumed to play a role of major importance in determining the abundance of the various year classes.

Twenty-two specimens of *kennicotti* were sexed during the season. Of these, 15 were found to be males. Wynne-Edwards (1952) mentions that in the Mackenzie River there were as many as 15 females to every male at the time of spawning.

Body length and Scale-length Relationship: Examination of a scatter diagram (Fig. 1) of the fork length in millimeters (Y), plotted against the antero-lateral scale radius in millimeters times 43 (X), indicated that a straight line relationship may be postulated. The least squares equation calculated for the data is $Y = 57.2 + 1.92\ X$. Assuming that a straight line relationship exists between body length and scale length, it is possible to use the annular distances read directly from the enlarged scale images instead of (as is usually the case) the body length as calculated from the scale length. Thus, each scale length is systematically multiplied by 43, and, unless otherwise noted, growth is discussed in terms of scale size rather than fish length. Mottley (1941), working with the scales of the rainbow trout, states: "If it can be shown that the scale provides an unbiased estimate of the length or size of the fish, then there is no real reason for the conversion of the scale into body size for the comparison of growth."

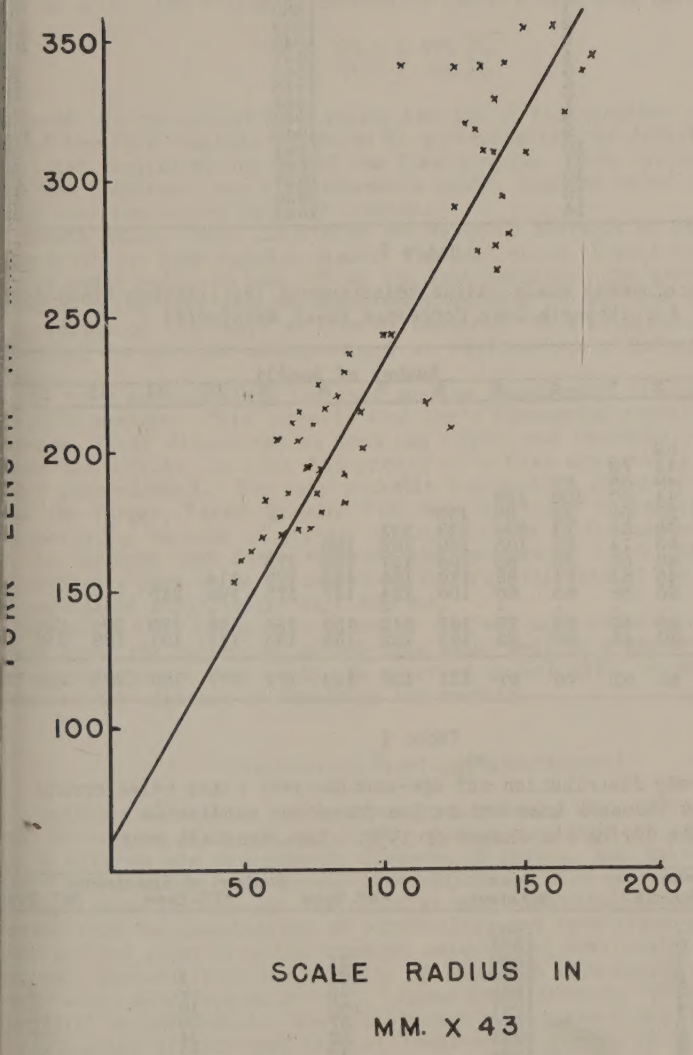

FIG. 1. Body-length and scale-length relationship in *Coregonus nasus ennicotti*.

Table 1

Age-frequency distribution and year of spawning relationships for Ikroavik Lake *Coregonus nasus kennicotti* during the summer of 1952

Age	Number of Annuli	Year Spawned	Number of Fish
0	-	1952	0
1	0	1951	0
2	1	1950	0
3	2	1949	14
4	3	1948	16
5	4	1947	1
6	5	1946	8
7	6	1945	5
8	7	1944	7
9	8	1943	1
10	9	1942	13
11	10	1941	1
12	11	1940	1
13	12	1939	0
14	13	1938	5
15	14	1937	1

Table 2

Average anterolateral scale radius measurements (millimeters times 43) for Ikroavik Lake *Coregonus nasus kennicotti*

Age	No. of Fish	Number of Annuli													
		1	2	3	4	5	6	7	8	9	10	11	12	13	1
1	0														
2	0	-													
3	16	23	52												
4	15	21	41	72											
5	1	22	49	68	87										
6	7	21	41	67	102	128									
7	5	21	37	62	70	88	113								
8	7	19	38	54	71	104	110	131							
9	1	26	53	74	93	105	136	162	195						
10	13	21	40	56	73	88	108	127	152	178					
11	1	21	45	61	71	88	110	125	152	175	214				
12	1	23	36	53	65	86	106	124	147	175	192	215			
13	0	-	-	-	-	-	-	-	-	-	-	-	-		
14	5	21	36	43	62	78	117	112	135	154	168	185	204	224	
15	1	16	30	48	62	82	103	122	134	155	171	191	198	213	23
Weighted Average		21	42	61	76	97	111	126	149	171	177	190	203	222	23

Table 3

Age-frequency distribution and age-annulus-year class relationship in Ikroavik Lake and marine *Coregonus sardinella* taken during the summer of 1952. Data from all gear.

Age	Number of Annuli	Year Hatched	Number of Specimens "F" Type	"X" Type	"M" Type
0	-	1952			
1	0	1951			
2	1	1950	31		
3	2	1949	567	1	
4	3	1948	65	9	2
5	4	1947	146	16	5
6	5	1946	37	36	19
7	6	1945	52	34	37
8	7	1944	42	17	50
9	8	1943	10	2	28
10	9	1942	2	1	6
11	10	1941	2		5
12	11	1940			1
Total			1014	116	153

The equation given above may be used to calculate fish length from any of the data presented. The constant 57.2 represents the point at which the curve intersects the ordinate, and in this case represents the approximate fork length at the time of scale formation. The slope of the line is the constant 1.92, which represents the relationship between 43 times the scale length and the fork length when both measurements are in the same units. All calculations were made in terms of the fork length (FL); however, measurements were made on the standard length (SL) and the total length (TL) as well. The following conversion factors have been calculated:

$$SL = 0.924\ FL$$
$$TL = 1.091\ FL.$$

FL to SL was calculated by dividing the sum of the standard lengths by the sum of the fork lengths, and FL to TL was calculated by dividing the sum of the total lengths by the sum of the fork lengths. Such calculations assume that the different length measurements bear a constant relationship to each other over the entire range of lengths.

Growth Rate: Table 2 contains the weighted averages of the scale radii (times 43) for each annulus-class. The last entry in each horizontal line is the scale radius (times 43) at the last annulus. Carlander (1950) suggests that the last annulus measurement be used rather than the entire radius length of the scale at time of capture. This eliminates growth differences due to fish being caught at various times during the growing season.

For each annulus-class the last annulus measurement is greater than the weighted average. This suggests that Lee's Phenomenon prevails. This phenomenon, first discovered by Rosa Lee (1912) and thoroughly discussed by Einar Lea (1913), is that the growth of a fish apparently decreases in older year-classes. The most probable explanation given by Lea (1913) is that the larger, faster growing fish have a greater mortality rate, either naturally, or because of greater susceptibility to fishing effort. In any of the Ikroavik Lake fish, however, the presence of Lee's Phenomenon would of necessity have to be explained by differential natural mortality because of negligible exploitation by fishermen.

Assuming that calculated sizes at various ages represent real size at those ages, the calculated growth data might well be a better indication of population growth than would the observed growth data, because more measurements are utilized in obtaining the results.

Coregonus sardinella (Valenciennes)

Coregonus sardinella (Valenciennes), a cisco or lake herring, is the second species on which age and growth studies were made during 1952. Except for a note on one specimen by Clemens, Boughton, and Rattenbury (1944) there are no other known growth observations on this species.

Population Differences Indicated by Scale Differences: Data were collected from two populations of *sardinella*, one from fresh-water Ikroavik Lake and the other from the brackish water inlet previously described. In general, the annuli of the majority of lake fish were marked by wide, clear bands which were free of circuli. These fresh-water or "F" type scales, as they will be referred to, are illustrated in Figures 2 and 3. (Fig. 4 is a photograph of the same type of fresh-water growth in the scale of an Ikroavik Lake *kennicotti*.)

In some Ikroavik Lake fishes a scale structure was noted which was distinct from that of the usual fresh-water type. The second kind of growth, henceforth referred to as type "X" and illustrated by Figures 5 and 6, was

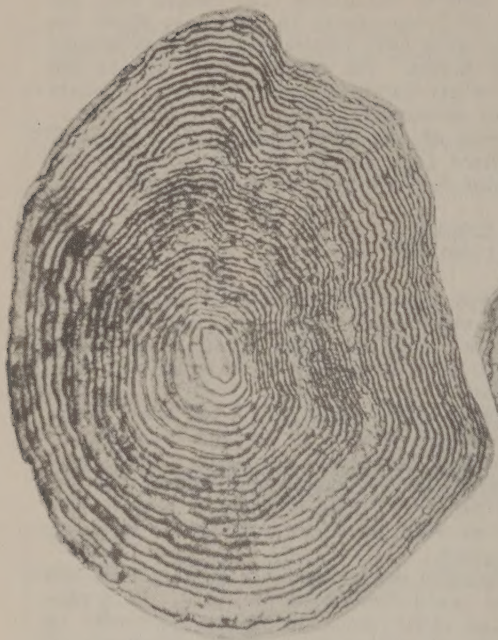

FIG. 2.
"F" type scale from *Coregonus sardinella*.

FIG. 3.
"F" type scale from *C. sardinella*.

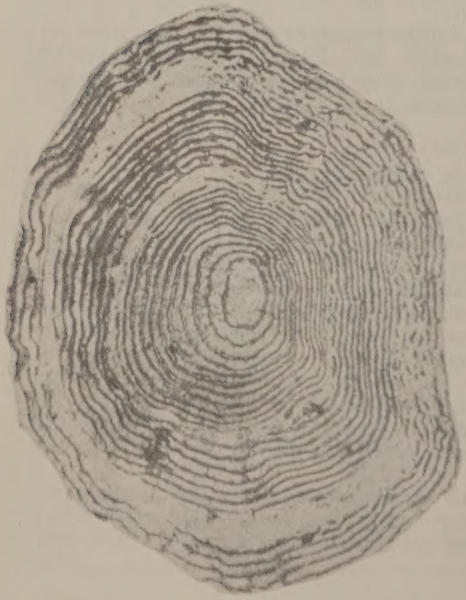

FIG. 4.
"F" type scale from *C. nasus kennicotti*.

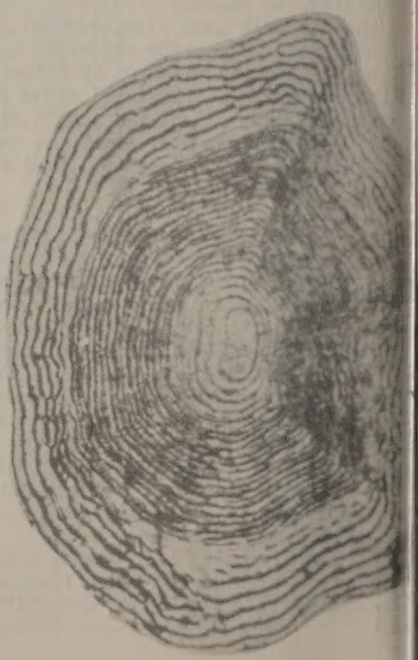

FIG. 5.
"X" type scale from *C. sardinella*.

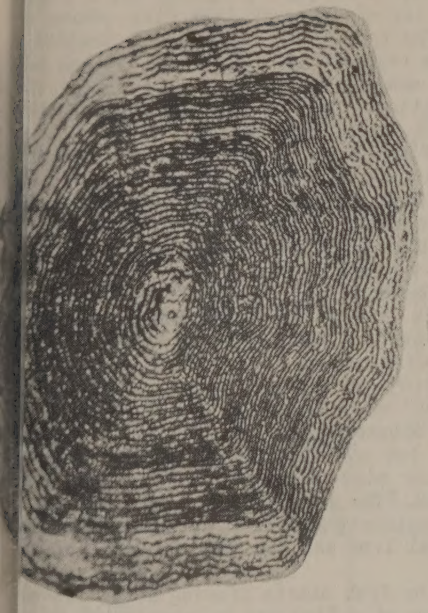

FIG. 6.
"" type scale from *C. sardinella*.

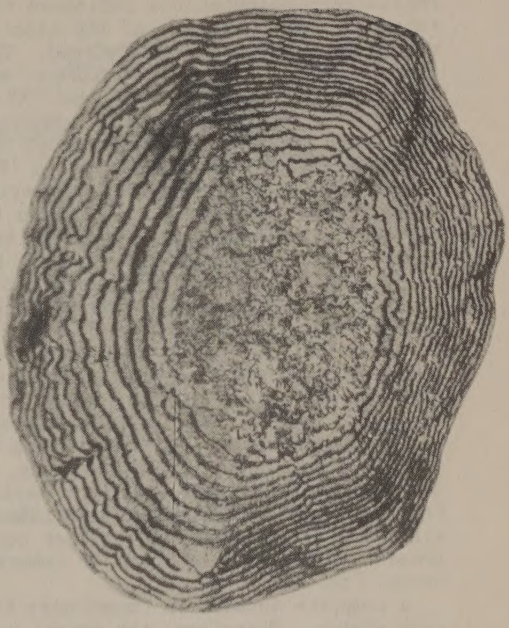

FIG. 7.
Regenerated scale from *C. sardinella*.

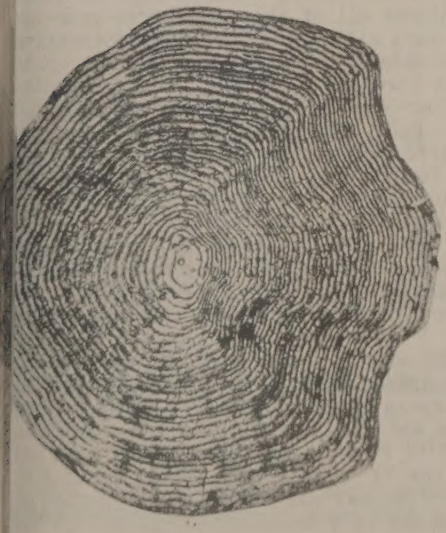

FIG. 8.
"M" type scale from *C. sardinella*.

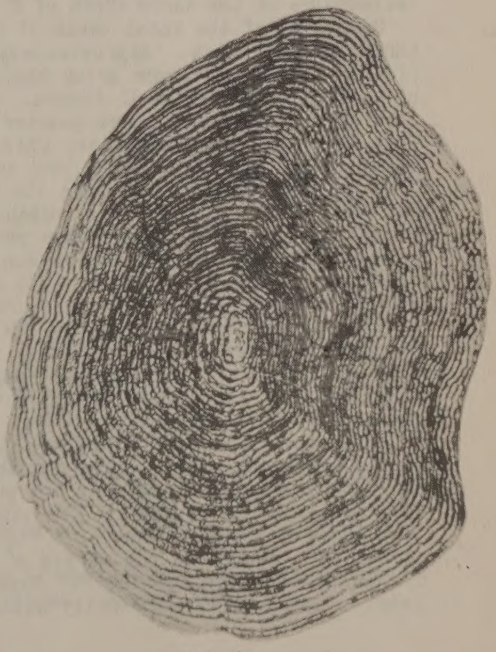

FIG. 9.
"M" type scale from *C. sardinella*.

very difficult to interpret because the circuli were quite close together. Preliminary calculations indicated that the type "X" group had a growth rate different from that of the majority of Ikroavik Lake fish, whose annuli and circuli were well defined. The type "X" fish have been treated as a separate population. A picture of a regenerated scale (Fig. 7) has been included for comparison with type "X" scales, to remove any suspicion that the type "X" scales represent regeneration. The differences shown by this photograph should be striking enough to dispel this notion.

The scales of marine *sardinella* (Figs. 8 and 9) were found to be different from either of the types previously discussed. Their circuli are farther apart and more evenly spaced than those of the type "X" fish, and the annuli are marked by a crowding together of the circuli, although the degree of crowding does not approach that found in the scales of type "X" *sardinella*. These will be referred to as type "M".

Spawning and Hatching: Observations during the course of the summer indicated that *C. sardinella* in Ikroavik Lake spawn in September, probably at about the time of the fall freeze-over. They hatch out under the ice and develop scales during the following summer. A series of 93 small *sardinella*, varying in size from 42 to 93 mm. in fork length, was captured on July 31, 1952. Thirty-two of these fish, ranging in size from 42 to 59 mm., had no scales. Thirty-two fish between 50 and 64 mm. in length had scales forming on the caudal peduncle, but none was present on the area between the lateral line and the anterior edge of the dorsal fin, the area from which all scale samples were taken. The remaining 29 fish, ranging in size from 49 to 93 mm., were either completely scaled or at least had scales present in the area between the lateral line and the anterior edge of the dorsal fin.

A complete annulus is formed when the fish starts growing after its second winter. Therefore, the actual age of a fish may be considered to be the number of annuli plus one.

Age-Frequency: The age-frequency data and the age-annulus-year-class relationships of the three types of *C. sardinella* are summarized in Table 3.

Over half of the total catch of fish with "F" type scales consisted of three-year-old fish. Approximately 50 per cent of these three-year-old fish were captured in one seine haul which evidently went through the heart of a large school of small fishes. Almost all of the other three-year-old fish were captured in three-quarter inch gill nets. Greatly contrasting with the three-year-old fish, which made up 54.3 per cent of the total catch of "F" type *sardinella*, and the five-year-old fish, which comprised 15.3 per cent of the catch, are the four-year-old fish, which are only 6.7 per cent of the total "F" type catch. Point Barrow weather records for the winters during which the three year-classes under consideration were spawned fail to indicate any reason for the significant variation in the magnitude of the year classes. It would seem that age-specific survival effects of an unknown nature were present in the environment.

If the age-class frequencies for "F" type fish from 1947 to 1941 are considered a catch curve, it can be seen, as pointed out by Wohlschlag (in press), that the mortality rate increases with the age of the fish. He discusses the phenomenon of age-specific mortality more thoroughly and states that there is no known cause.

Reference to Table 3 shows that the mode of the "X" type *C. sardinella* is the 1946 year-class, while the secondary mode of the "F" type fish is the 1947 year-class. This is not surprising when viewed in light of the fact that the fishes bearing "F" type and "X" type scales are not members of a homogenous population. The majority of "X" type scales shows a period of "F" type growth at the margin of the "X" type growth (Figs. 5 and 6). The indication is that the "X" type fish may not be native to Ikroavik Lake. This will be more fully discussed in a section to follow. It is

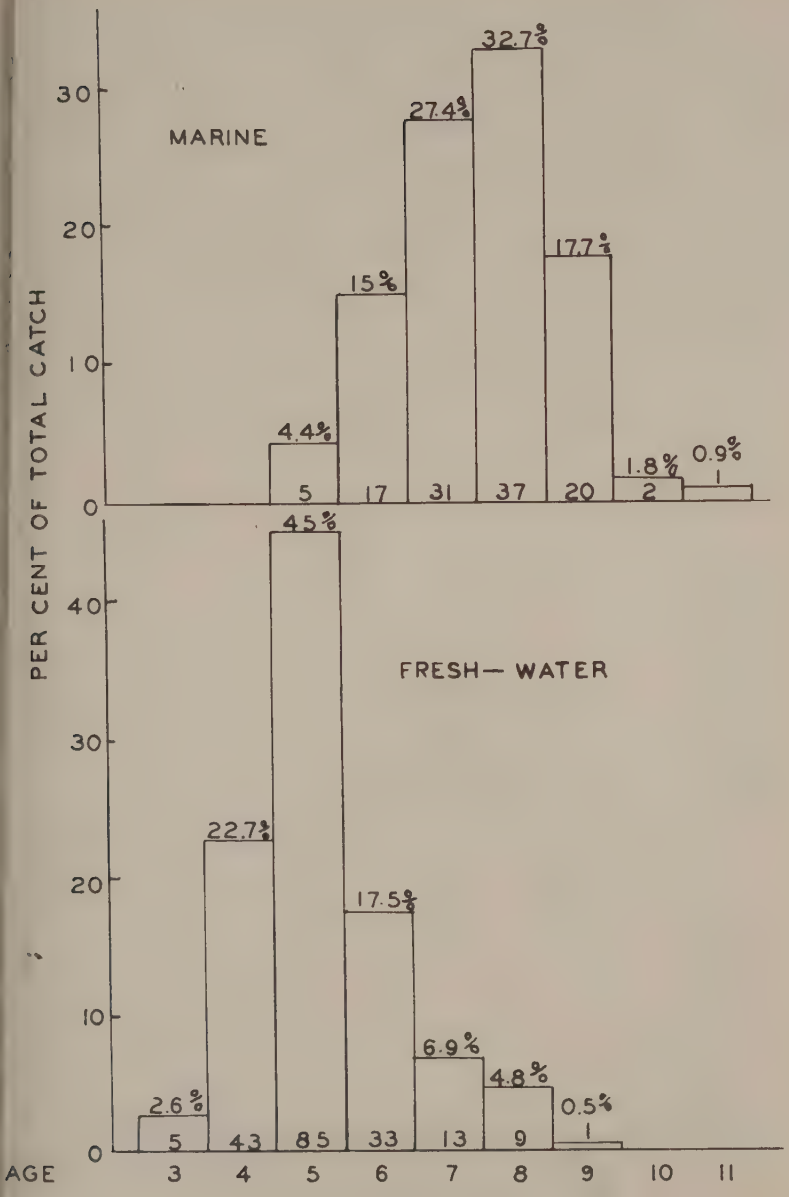

FIG. 10. Age-frequency distribution of marine and Ikroavik Lake *Coregonus sardinella* taken in a one-inch gill net. Summer, 1952.

assumed that the same amount of catch effort with identical gear was directed towards both populations. As will be shown later, each of the scale types reflects different growth rates; therefore, the age-length relationship would be different in each population, and a similar age-frequency distribution would not be expected when sampling with a given type of gear. Of the total catch of fish with "F" type scales, 64.3 per cent consisted of fish under five years of age, while only 8.7 per cent of the fish with "X" type scales were under five years of age. This may be due to selectivity of the gear. Possibly there were no smaller fish among the group of "X" type fish which presumably had entered the lake in previous years.

Figure 10 shows age-frequency distributions of two populations of *C. sardinella* caught in a one-inch mesh gill net. One population is marine and was caught in the brackish water inlet previously mentioned. The other population is fresh-water and was taken in Ikroavik Lake. It would seem that a size-selective factor, which would contribute to the differential selection in age-classes by the net in each location, was in operation.

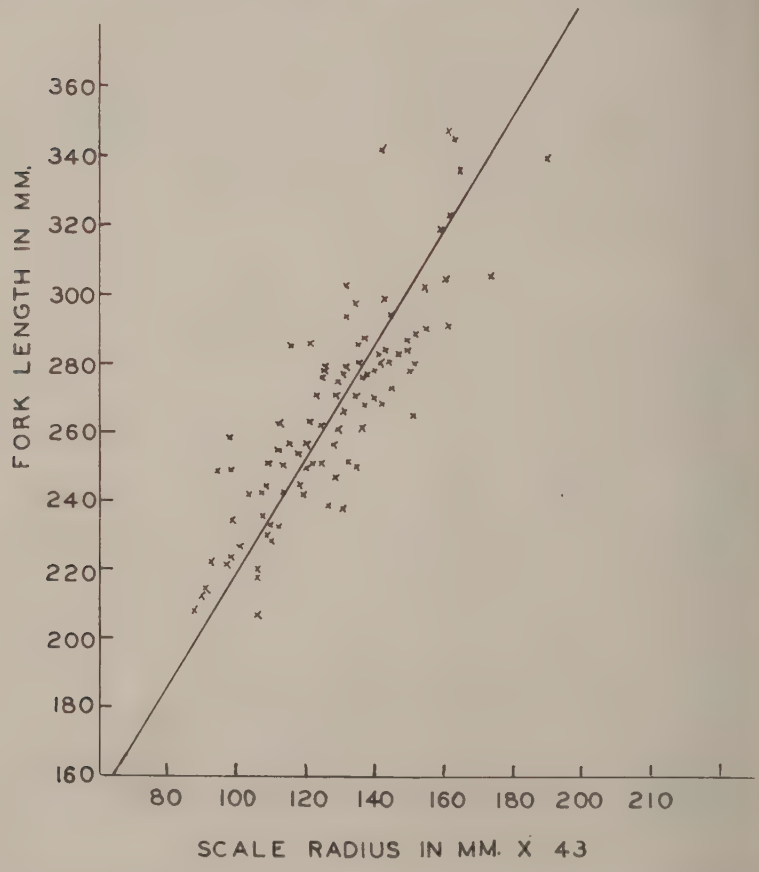

FIG. 11. Body-length and scale-radius relationships in marine type *Coregonus sardinella*.

The most casual observation indicated a marked difference between the b y shapes of the marine and fresh-water fishes; the marine fish were s ller for their ages and more slender than the fresh-water fish of the s e age. These observations were confirmed by Point Barrow Eskimos who h l long noted the differences between the two forms. Morphometric dif- f ences between the two populations are more thoroughly analyzed by W lschlag (1954).

Body-length and Scale-length Relationships: Fork length in millimeters (), plotted against the scale radius in millimeters times 43 (X), for m ine *C. sardinella* is presented in Figure 11. The regression is assumed t be a straight line with the following equation calculated by the least s ares method: Y = 52 + 1.68 X. In this case 52 millimeters can be as- s ed to be the approximate fork-length of the fish at the time of scale r mation.

The straight line which represents the body-length and scale-radius re- l tionships in type "X" *C. sardinella* is Y = 78 + 1.44 X. The regression w s calculated by the least squares method and is graphed in Fig. 12.

The regression, log Y = 1.077 + 0.636 log X, was calculated for a sam- p e of 200 *C. sardinella* showing the "F" type of scale growth. It is plot- t d in Fig. 13. As in the previous regressions, Y is the fork length in m llimeters, and X is 43 times the scale radius in millimeters.

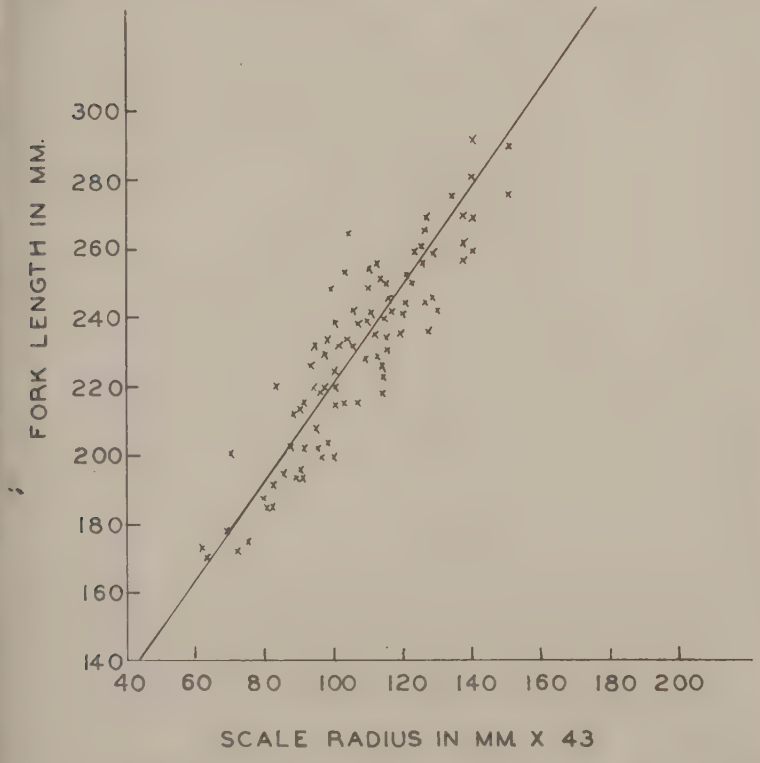

FIG. 12. Body-length and scale-radius relationships in "X" type *Coregonus sardinella*.

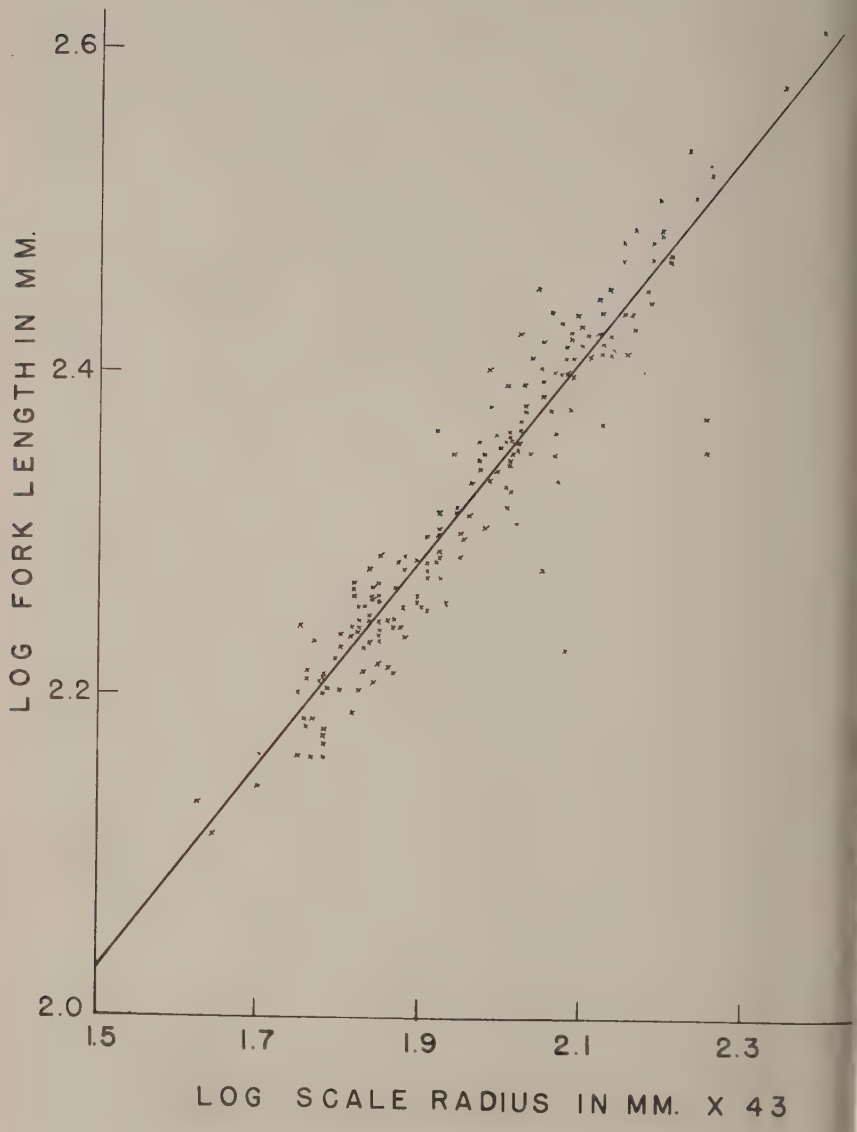

FIG. 13. Body-length and scale-length relationships in "F" type *Coregonus sardinella*.

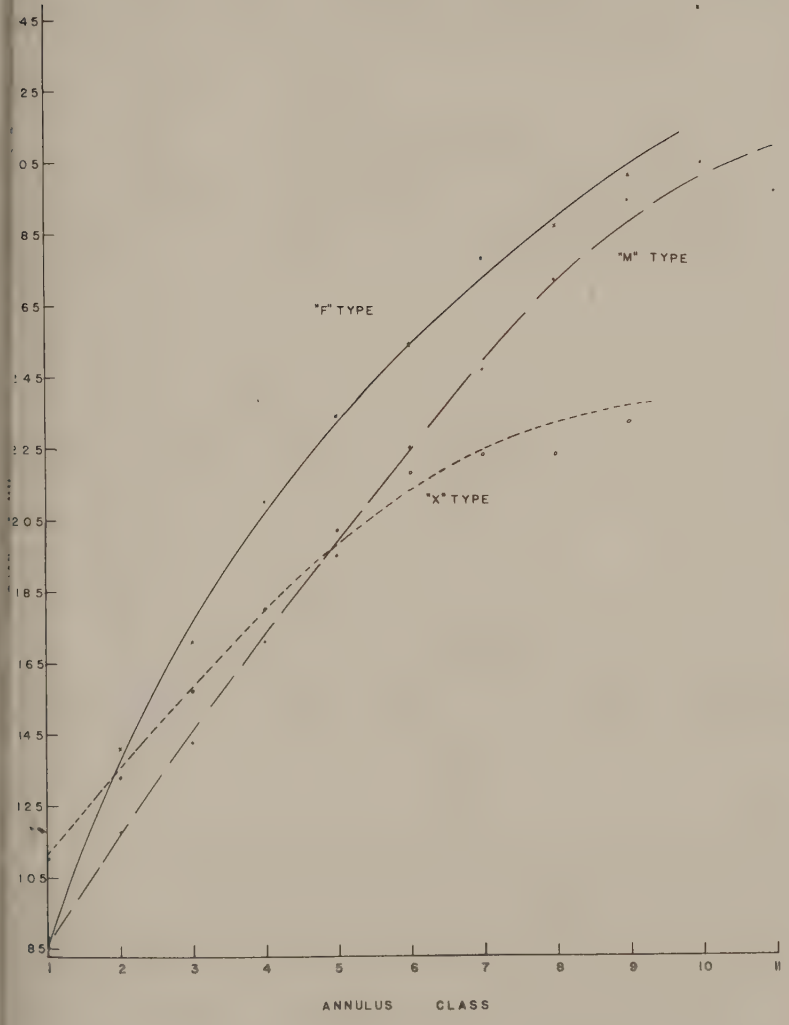

FIG. 14. Growth of three populations of *Coregonus sardinella*. (See ext.)

Growth Rates: Growth rates for the populations with "M" type and "X" type scales were calculated on the assumption that the fork length and the length of the antero-lateral scale radius are directly proportional. "M" type *C. sardinella* growth is summarized in Table 4, and "X" type growth is summarized in Table 5. Growth of "F" type *sardinella* is summarized in Table 6. All three of these tables may be interpreted in the same manner as Table 2. Inasmuch as the scale length-fork length relationship in "F" type *sardinella* is not a direct proportion, the scale length data have been back-calculated to give the fork lengths in millimeters at each annulus. In all three of the populations a comparison of the last annulus figures with their corresponding weighted average figures indicates the presence of Lee's Phenomenon. What has already been said about Lee's Phenomenon as it applies to *kennicotti* also holds true for the three populations of *sardinella* under consideration.

The growth rates of the three *C. sardinella* populations are compared in Fig. 14. The curves are drawn from the weighted average growth figures (fork length in millimeters) for each annulus class. For the "X" type and "M" type populations the figures have been converted from scale length in millimeters times 43 to fork length in millimeters by use of the appropriate formulas given in the section above.

Whitefishes found living in Ikroavik Lake grow at a greater rate and attain larger size than those dwelling in the ocean or in brackish water. This growth pattern is exactly the reverse of that found in many anadromous salmonids in more temperate regions. The most probable explanation is that the average ocean temperatures around Point Barrow during the growing season of the whitefish are lower than the average temperatures in the shallow, fresh-water lakes during the same period. Van Oosten (1923), working with *Coregonus* in an aquarium, found that, other conditions being equal, temperature was the factor which influenced the seasonal growth variations of the fish.

The "X" type fish present a puzzling growth curve which intersects the other two curves and shows a more pronounced decrease in rate of growth with age than do the other two populations.

As previously mentioned, most of the "X" type scales which were examined seem to show a marginal area, sometimes as much as two annuli, consisting of "F" type growth. Scales from three specimens of *kennicotti* captured in Ikroavik Lake also showed "X" type growth, thus indicating that scale-pattern difference is probably an environmental rather than an hereditary phenomenon. The question at once raised is: what is the origin of the fishes carrying "X" type scales? One could postulate that fish carrying "X" type scales were marine fish which had run into fresh water; however, no fish with "X" type scales were taken outside of Ikroavik Lake, although admittedly little collecting was done outside of the lake. Furthermore, 33 fishes with definite "M" type of scale growth were taken from Ikroavik Lake. The indication is, then, that "X" type fish do not originate in Ikroavik Lake, but migrate into it. The possibility of migration is indicated by the presence in the lake of fish with "M" type scales, the presence of fish with "X" type scales bearing marginal "F" type growth, and by the capture there of two adult sexually mature salmon (*Oncorhynchus keta*). From what little was seen of the lake's outlet stream it could not be called a suitable or permanent habitat. There is, however, the possibility that its nature changes farther downstream. Between the origin of the outlet of Ikroavik Lake and its ultimate entrance into Iko Bay, an arm of Elson Lagoon, there is another lake. Several persons who have visited it expressed the doubt that the lake was deep enough to contain a permanent fish population. As far as is known, however, no experimental fishing has been attempted, and the possibility that the lake is a habitat for "X" type fish cannot be ruled out. Still farther down, where the stream enters Iko

Table 4

Calculated growth of "M" type *Coregonus sardinella* expressed as scale-radius in millimeters times 43

Age	Number of Fish	Number of Annuli 1	2	3	4	5	6	7	8	9	10	11
	0											
	0	-										
	0	-	-									
	2	26	48	72								
	5	18	31	55	78							
	19	19	36	56	73	91						
	37	23	43	58	75	93	108					
	50	22	39	56	71	87	103	118				
	28	20	37	46	68	82	98	114	126			
	6	21	37	53	69	88	100	121	136	150		
	5	17	32	46	58	79	98	114	130	141	154	
	1	19	33	51	62	78	86	100	115	124	134	145
Weighted Average		21	39	54	71	88	103	116	128	144	151	145

Table 5

Calculated growth of "X" type *Coregonus sardinella* expressed as scale-radius in millimeters times 43

Age	Number of Fish	Number of Annuli 1	2	3	4	5	6	7	8	9
	0									
	0	-								
	1	25	46							
	9	24	46	69						
	16	22	38	55	80					
	36	23	40	56	75	98				
	34	21	37	54	68	82	103			
	17	21	36	49	62	74	89	109		
	2	14	25	34	44	54	65	78	105	
	1	16	32	41	53	65	76	85	93	107
Weighted average		22	38	55	71	86	97	101	101	107

Table 6

Calculated growth of "F" type *Coregonus sardinella* expressed as fork-length in millimeters

Age	Number of Fish	Number of Annuli 1	2	3	4	5	6	7	8	9	10
1	0										
2	31	112									
3	567	88	152								
4	65	85	132	191							
5	146	86	130	175	228						
6	97	87	124	165	208	247					
7	57	83	123	157	191	225	257				
8	42	88	125	160	187	223	254	283			
9	10	84	118	154	184	214	243	268	292		
10	2	82	123	160	183	207	225	251	265	281	
11	2	89	119	156	181	211	235	258	287	321	348
Weighted average		88	141	171	210	234	254	278	287	301	348

Bay, it is a known fish habitat. Mr. John Thomas, of Stanford University, who has investigated this area, informs me (personal communication) that portions of the tidal estuary may be as deep as ten feet. The location is reported to be used on occasion as an Eskimo fish camp. Unfortunately, no fish were taken from the Iko Bay area during this study.

Differences among the three *C. sardinella* populations are also emphasized by the disagreement in body-length and scale-length relationships. Even though two of the regressions are linear, each has a different slope and a different ordinal intercept.

Figure 15 illustrates the relationship between the average annual growth increments for all year-classes and the average Point Barrow air temperatures during the growing season of May to September (calculated from data in Stettler, 1952). The "X" type fish, and to a lesser extent, the "F" type fish, show some degree of correlation between air temperature and growth. A correlation might not be expected to be as readily discernible in marine as in fresh-water fishes. Ocean currents and the proximity of drifting ice masses during certain years could do much to offset a clear-cut relationship between local air temperatures and water temperatures in any given marine location.

Fresh-water Fishery Potentialities of the Area

From the work of Wohlschlag (1953) on population estimates of Ikroavik Lake fish, and from what was learned in the present study on growth rates, it seems possible to draw at least two conclusions concerning the fresh-water whitefish in the area of Point Barrow. First, the populations are small; and second, the populations are slow growing. (Although there are indications that the fishes grow rapidly during the short season available for growth, the overall picture, which is the most important for management purposes, is one of slow growth of the resource as a whole). The possibility of a commercially important fishery for export to other regions seems out of the question, especially since only air transportation is presently available. There is little doubt, however, that local whitefish populations could stand more short-term exploitation by Eskimo fishermen for local use.

With regard to river populations of whitefish, a great deal more life history work remains to be done before these populations can be seriously considered as a food resource.

Summary

Two species of coregonine fishes, *Coregonus nasus kennicotti* Milner and *Coregonus sardinella* (Valenciennes) were collected in the area of Point Barrow, Alaska. *Coregonus nasus kennicotti* was taken from fresh-water Ikroavik Lake. *Coregonus sardinella* was taken in Ikroavik Lake and in the brackish inlet.

Coregonus nasus kennicotti spawns in July or earlier in Ikroavik Lake. The eggs take from 30 to 60 days to hatch rather than the 100 to 150 days more common in other coregonine fishes. The reason for the more rapid hatching may be that the lake experiences its peak temperatures during the spawning and hatching period. To obtain the true age of *C. n. kennicotti* it is necessary to add one to the number of annuli as the first annulus is not laid down till the end of the second year. Abundance of various year-classes is highly irregular; however, this may be due to the small absolute size of the sample. Of 22 specimens sexed, 15 were males and seven were females. The body-length antero-lateral scale-length relationship was

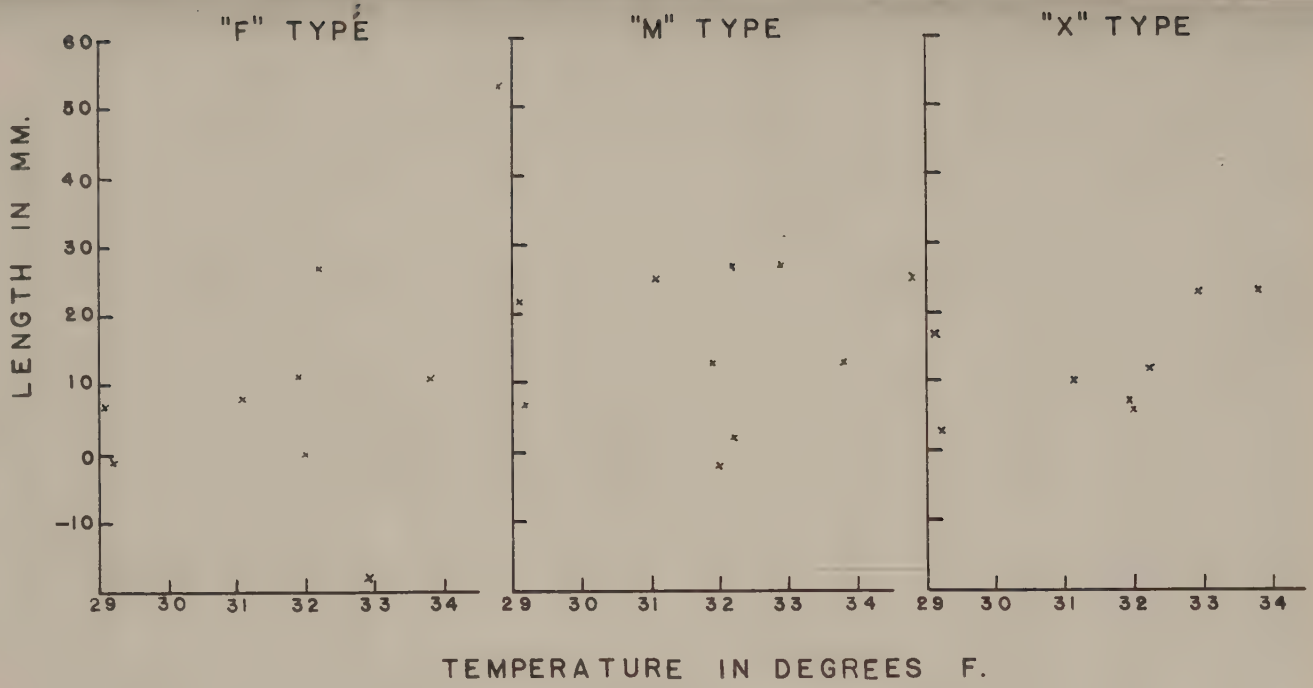

FIG. 15. Relationship between calculated average increment of growth in *Coregonus sardinella* and average May-September temperature at Point Barrow.

found to be a straight line described by the regression Y = 57.2 + 1.92 X. Examination of the growth data indicates the presence of Lee's Phenomenon.

Coregonus sardinella populations were divided into three groups on the basis of the structure of the scales. Two groups were taken in Ikroavik Lake. One of them, called "F" type, had the annuli marked by wide clear bands. The other group, called "X" type, had the annuli marked by an extreme crowding together of the circuli. A third group consisted of fishes taken for the most part in brackish water. These fish, which had evenly spaced circuli, and annuli with no clear bands, were called type "M".

Spawning of *C. sardinella* in Ikroavik Lake takes place in September. Hatching occurs under the ice. The fish are between 54 and 60 mm. in fork length when scales form in the area between the lateral line and the anterior edge of the dorsal fin, where scale samples were taken. To obtain the correct age of *sardinella,* it is necessary to add one to the number of annuli. Examination of age-frequency data for fish with "F" type scales indicates the presence of unknown age-specific survival effects. Catch data with identical gear of *sardinella* in Ikroavik Lake and in the brackish inlet indicate a difference in body shape of the two populations. The body length-scale length relationship of "M" type *sardinella* is represented by the straight line Y = 52 + 1.68 X. The body length-scale length relationship of "X" type *sardinella* is represented by the straight line Y = 78 + 1.44 X. The body length-scale length relationship of "F" type *sardinella* is represented by the logarithmic equation log Y = 1.077 + 0.636 log X. Lee's Phenomenon is indicated for all three populations of *sardinella.* A comparison of the growth rates of all three populations shows "F" type fish with the greatest and "M" type fish with the least rate of growth. The "X" type curve intersects the other two.

"X" type fish do not appear to originate in Ikroavik Lake but migrate into it from another location.

There seems to be some correlation between average annual growth increments and average Point Barrow air temperatures for "X" type and "F" type fish. There is none in "M" type fish.

The fresh-water fish of the area are few and slow growing. The possibility of a major commercial fishery seems improbable.

LITERATURE CITED

BLACK, Robert F., and William L. BARKSDALE
1949 Oriented lakes of northern Alaska. Journ. Geol., vol. 57, no. 2, pp. 105-118, 6 pls., 1 map.

BOWERS, George M.
1900 A manual of fish culture. U.S. Comm. Fish and Fisheries. 340 pp., plates 1-64, I-XVII, 39 text figs. Washington.

CARLANDER, Kenneth D.
1950 Some considerations in the use of fish growth data based upon scale studies. Trans. Amer. Fisher. Soc., vol. 79 (for 1949), pp. 187-194.

CLEMENS, W. A., R. V. BOUGHTON, and J. A. RATTENBURY
1945 A preliminary report on a fishery survey of Teslin Lake, British Columbia. Report British Columbia Fisher. Dept., (for 1944), pp. 70-75.

DOWNING, S. W.
1904 The whitefish; some thoughts on its propagation and protection, Trans. Amer. Fisher. Soc., vol. 33, pp. 104-110.

KIEL, Peter
1874 Letters relating to the white-fish of Lake Ontario. Rept. U.S. Fish Comm. for 1872-1873, vol. 2, pp. 81-84.

IGLER, Karl F.
1952 Freshwater fishery biology. 360 pp., 172 text figs., appendices. Wm. C. Brown Company, Dubuque, Iowa.
LA, Einar
1913 Further studies concerning the methods of calculating the growth of herrings. Cons. Perm. Pour L'Expl. de la Mer, Publ. de Circonstance, no. 66, 35 pp. Copenhagen.
IE, Rosa M.
1912 An investigation into the methods of growth determination in fishes. Cons. Perm. Pour L'Expl. de la Mer, Publ. de Circonstance, no. 63, 35 pp. Copenhagen.
IGENDRE, V.
1954 Game and commercial fishes of the province of Quebec. The freshwater fishes, vol. 1. First English ed. Game and Fisher. Dept. Prov. Quebec, 180 pp., 80 figs.
ITTLEY, C. McM.
1942 The use of the scales of the rainbow trout (*Salmo gairdnerii*) to make direct comparisons of growth. Trans. Amer. Fisher. Soc., vol. 71 (for 1941), pp. 74-79.
ICE, John W.
1940 Time-temperature relations in the incubation of the whitefish *Coregonus clupeaformis* (Mitchill). Journ. Gen. Physiol., vol. 23, pp. 449-468.
ETTLER, Karl D.
1952 Local climatological summary with comparative data, 1951, Barrow, Alaska. U.S. Dept. Comm., Weather Bureau. 4 pp. Kansas City.
AN OOSTEN, John
1923 A study of the scales of whitefishes of known age. Zoologica (New York), vol. 2, no. 17, pp. 380-412, 6 pl.
1929 Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fisher., vol. 44 (for 1928), pp. 265-428, 43 figs.
ILIMOVSKY, Norman J.
1954 Provisional list of the fishes of Alaska. Tech. Rept. 5. Contract N6 ONR 25136, 35 pp. Multilithed.
Utilization of fishery resources by the Arctic Alaskan Eskimo. Proc. Third Alaska Sci. Conf., Sept. 22-27, 1950. In press.
OHLSCHLAG, Donald E.
1953 Some characteristics of the fish populations in an Arctic Alaskan lake. In: Current research in the Alaskan Arctic. Stanford Univ. Publ., Biol. Sci., vol. 11, pp. 19-29.
1954 Growth peculiarities of the cisco, *Coregonus sardinella* (Valenciennes), in the vicinity of Point Barrow, Alaska. Stanford Ichth. Bull., vol. 4, no. 3, pp. 189-209, 3 figs.
Mortality rates of whitefish in an arctic lake. Ecology. In press.
YNNE-EDWARDS, V. C.
1952 Freshwater vertebrates of the arctic and subarctic. Fisher. Res. Bd. Canada, Bull. 94, 28 pp., 3 figs.

GROWTH PECULIARITIES OF THE CISCO, *COREGONUS SARDINELLA* (VALENCIENNES), IN THE VICINITY OF POINT BARROW, ALASKA[1]

By Donald E. Wohlschlag

The purpose of this paper is to describe quantitatively some differences i the growth patterns and body forms of the ciscoes (*Coregonus sardinella*[2]) vich occur in both marine and fresh-water populations in northernmost Alaska. Attention was called to the problem by the local Eskimos who recognize that several species of coregonids, including *C. sardinella*, vich occur both in marine coastal and in fresh inland waters, have "skinny" forms in the streams and coastal waters, while those from the lakes are 'at." Similar reports have been made by the natives of the Ungava Bay rea of Canada (Dunbar and Hildebrand, 1952). Svärdson (1951) has reported tat the coregonid "älvsik" in the river Bure and the slightly saline Gulf c Bothnia had slender forms with relatively long snouts, while the same fsh stocked in Swedish fresh-water lakes attained a different form and reater growth rates. Järvi (1950) in Finland also has observed growth fferences between the brackish and fresh-water forms of the whitefish, *oregonus albula*. Thus it would seem that any study of fishes such as oregonids, which occur in diversified environments, should begin by the ecognition of population boundaries insofar as fish morphometry and environmental conditions be related.

Although a great amount of systematic work has been carried out on the oregonidae of central Europe, Fennoscandia, U.S.S.R., Canada, and the nited States, the plasticity among the various "species" as revealed by any localized growth forms has prevented a clear distinction between environmental and genetic influences on morphology. However, since the oregonidae in many relatively isolated glacial lakes throughout the north emperate and subarctic regions are known to have local growth forms, it as assumed that such forms might exist in the unglaciated Arctic of the oint Barrow region. If the body form and growth rates of local populations could be demonstrated to be different from one environment to another round Point Barrow, the existence of population discreteness or heteroeneity at least could be defined for any given body of water even though ausal factors could not be discovered.

The problem of population discreteness arose when population and mortality rate estimates for the ciscoes of Ikroavik Lake were made (Wohlschlag, 953; and in press). These studies were carried out under the apparently ustified assumption that the lake fish were not influenced by migrating ndividuals during the course of field studies in the summer of 1952, but he possibilities of migrations at other times and of the occurrence of inividual races within the lake were recognized.

Cohen (1954) has discovered that three types of scale-growth patterns mong the ciscoes from waters near Point Barrow are associated with age-ength differences. As a result of his discovery, this study includes a tatistical examination of the length-weight relationships for fish belonging to each of the three scale-type groups.

The kind cooperation of Dr. Ira L. Wiggins, Director of the Arctic Research Laboratory at Point Barrow, and his staff to make the field operations in 1952 possible was greatly appreciated. Norman J. Wilimovsky, who

[1] This study is presented in partial fulfillment of Contract Nonr-225(08) with the Office of Naval Research.

[2] *Coregonus* must replace *Leucichthys*; see Cohen (1954).

is currently studying the systematics and distribution of fishes of the region, has been especially helpful in supplying information on systematics and in supplying data from a collection he made in 1951. Daniel M. Cohen aided in all the laborious field work and in the tedious mounting and reading of scales; his help in making this report possible is gratefully acknowledged.

Occurrence of the Cisco at Point Barrow

Dymond (1943) believes *Coregonus pusillus* (Bean) 1889 is an eastward extension of the Siberian form of *C. sardinella* (Valenciennes); hence the latter name will be used in this study. This species commonly occurs in the lakes of the northern arctic slope of Alaska. Only lakes which have connections to the sea and which are deep enough to prevent complete freezing to the bottom (over six feet) are known to contain this species. (So far as is known lakes isolated in the tundra contain no fish.) The cisco is also common in Elson Lagoon and tributary waters along the Arctic Ocean coast to the southeast of Point Barrow.

The shallow Elson Lagoon waters vary in salinity from nearly fresh when the ice melts in June or July to marine later in the summer. On the basis of sporadic gill net catches in the summer of 1952, it might be adduced that this species moves in small schools along the shores of the lagoon. Later in the summer, however, the gill net catches became smaller and it seems reasonable that many of the summer lagoon residents participate in the spawning migrations up the larger streams. These migrations are well known to the Barrow Eskimo, who report their occurrence in the late summer and autumn in the larger rivers entering the Admiralty Bay area some 50 miles to the southeast of Point Barrow. Of 38 ciscoes tagged and released in late July, 1953, in a tidal estuary of Elson Lagoon near Barrow, one was reportedly taken in early October, 1952, by a native fisherman near the Meade River coal mine, a distance of around 100 miles from the point of release. The report has remained unverified. There have been no other tagging operations in this area.

A substantial series of ciscoes was collected in Ikroavik Lake, the northernmost lake in Alaska containing a permanent fish population. The lake is located 6 miles south of the Arctic Research Laboratory at Point Barrow. It is 2.5 miles long and nearly one mile wide with a maximum depth of 7 to 7.5 feet over at least half its area. Ice freezes to a depth of at least 6 feet. In the summer of 1952 the lake was ice-free only from July 2 to September 25.

The fish faunas of the thousands of lakes and ponds, which occupy around 50 percent of the surface area to the south and east of Point Barrow, have not yet been investigated and considerable work will be necessary in order to ascertain the existence of permanent and migratory populations.

Collection of Data

During July 19-25, 1952, lengths were recorded for 116 ciscoes taken at the mouth of an Elson Lagoon tidal estuary located 4 miles southeast of the Arctic Research Laboratory; weights were recorded for 115 of the specimens. All individuals were taken with a gill net 100 feet long, 6 feet deep, with a 2-inch stretched mesh. At the same time and place, an additional 39 specimens were taken with a 200-foot, 1½-inch stretched mesh seine; lengths and weights were recorded for each of these fish. In addition Mr. Wilimovsky has supplied length and weight data for 39 specimens taken in experimental gill nets from the same location during July 19-20 in 1951

From July 30 to August 27, 1952, length and weight data were obtained from 178 specimens caught with the 2-inch mesh gill net in Ikroavik Lake. During the same period, 165 length and weight measurements were obtained from fish taken with the 200-foot seine. From September 3-10, 1952, 380 fish were taken in the lake with the 2-inch mesh gill net and with two 250-foot experimental gill nets each consisting of five 50-foot sections of 1½-, 2-, 2½-, 3-, and 4-inch meshes (stretched measure).

In both the estuary and lake collections, standard, fork, and total lengths were recorded to the nearest millimeter. Only the fork lengths will be used in this study. Weights were recorded to the nearest gram for most of the fish; a few fish heavier than 500 grams were weighed to the nearest two grams. Scale samples were taken from nearly all estuary fish and from all the lake specimens. Because many of the fish from the lake and estuary were marked and returned alive in the earlier part of the season, it was impossible to make much more than routine length and weight observations on most of them until the final September samplings. Sufficient data were obtained, however, to indicate in a general way the nature and extent of feeding activities, gonadal maturity, and parasitic infections.

In order to avoid sample biases caused by taking only the larger individuals of the youngest year-classes, this study will include only those which had fork lengths of 180 millimeters or longer and which could not possibly slip through the smallest 1½-inch stretched mesh in use. This procedure eliminated a consideration of chance retention of more-corpulent-than-average specimens which were slightly shorter than 180 millimeters. Altogether, however, about 1,000 specimens smaller than 180 millimeters were taken. It should be noted that among all fish from the lake, ages ranged from one to 11 years, with a natural "break" represented around the length of 180 millimeters for fish between three and four years old; while among those from the estuary, one three-year-old and two four-year-olds represented the youngest fish (Cohen, 1954).

Results

Field Observations: From general appearances, the ciscoes from the tidal estuary seemed to be somewhat thinner than the lake fish. Lake fish ordinarily contained great amounts of stored fat in their body cavities from the time of ice break-up until autumn and through the sexually immature stages to spawned-out adults. The tidal estuary specimens, on the other hand, lacked appreciable fat deposition. Among the lake specimens a few were unusually thin; and of those examined internally, parasitic infection (probably dibothriocephalids) was intense. The thin lake specimens and the majority of the estuary specimens seemed to have somewhat darker dorsal pigmentation and somewhat more rounded snouts than the majority of lake fish, but these differences were at best vague. Among both lake and estuary fish, a few individuals were strikingly deep-bodied; some of these possessed obvious spinal deformities resulting in shortened caudal peduncles; but most had no externally evident skeletal abnormalities. Stomach contents were observed only casually, but both estuary and lake fish almost always had their stomachs full, so the differences were apparently not caused by stomachs gorged with food.

Length-frequency Differences Between Selected Samples of Lake and Estuary Fish: To investigate the existence of any difference in relative body depth between marine and lake forms, the 2-inch gill net collections made in these two locations were compared on the basis of their length-frequency distributions (Table 1). The two collections might be considered as stratified samples, since the same net was used for both collections and since its meshes should be selective for fish with uniform average girth

measurements more or less independently of fish lengths. A comparison o the observed length-frequency data of Table 1 may be analyzed by the con ventional chi-square method (Snedecor, 1946, Chapter 9). Upon comparin the observed and expected frequencies of occurrence in the various leng groups, it will be observed immediately that in the smaller length group ings the lake fish were retained in greater proportions while in the large length groups the estuary fish were retained in greater proportions. Th highly significant chi-square value of 40.45 with a probability of chanc occurrence of less than 0.001 indicates that the two length-frequency dis tributions were really different with the implication that, length fo length, the lake forms were deeper-bodied than the estuary forms.

Table 1

Chi-square test of homogeneity of length-frequency groupings of the ciscoe (*Coregonus sardinella*) from fresh-water Ikroavik Lake and a brackish tida estuary of Elson Lagoon near Point Barrow, Alaska. Both collections mad with the same 2-inch (stretched) mesh gill net

Length Groups (millimeters)	Estuary July 19-25		Lake July 30-August 27		Total
	Observed	Expected	Observed	Expected	
219 and less	3	16.57	39	25.43	42
220-229	9	13.02	24	19.98	33
230-239	10	13.81	25	21.19	35
240-249	17	14.20	19	21.80	36
250-259	21	19.73	29	30.27	50
260-269	18	15.78	22	24.22	40
270-279	20	12.63	12	19.37	32
280 and over	18	10.26	8	15.74	26
Totals	116		178		294

Chi-square = 40.45; degrees of freedom = 7; probability less than 0.001

Length-weight Relationships Between Lake and Estuary Fish: The lengt weight relationships of 183 ciscoes from the tidal estuary and 724 fr Ikroavik Lake are plotted in Figure 1. From a visual comparison of t lake fish (dots) and the estuary fish (x's), it will be noticed that f any given length the lake fish are generally heavier. The wide departur from the "normal" lake forms (open circles and triangles) and the depa tures from the "normal" estuary forms (open squares) tend to obscure good graphical representation of clear-cut differences between fish fr the two locations.

The length-weight relationships as expressed in Figure 1 follow qui well a curve of the form,

$$\text{Weight in grams} = A\ (\text{fork length in millimeters})^{b},$$

where A and b are constants. For the data in logarithmic form,

$$\log \text{weight} = a + b \log \text{fork length},$$

so that the equation can be plotted as a straight line with intercept a a slope, or regression, b.

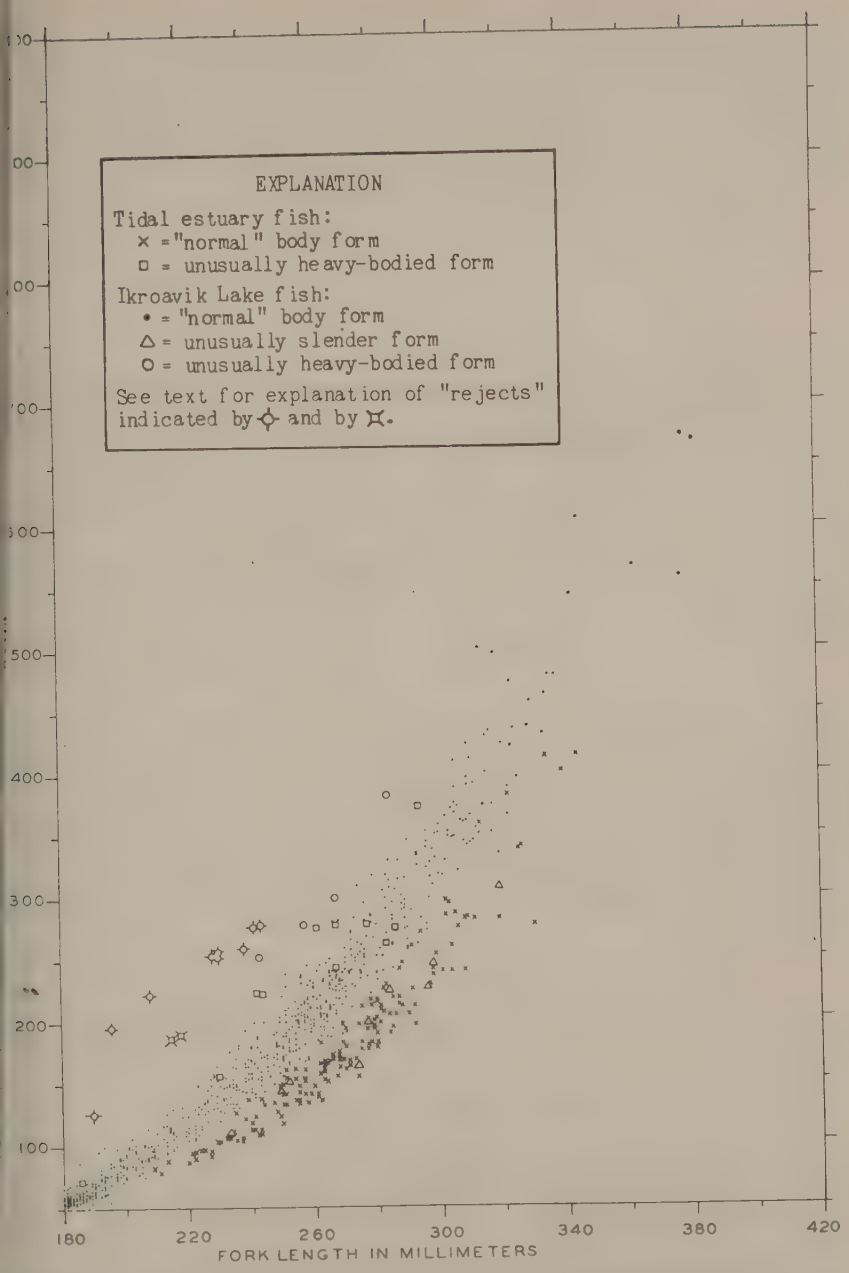

FIG. 1. Weight in grams plotted against length to fork of tail in millimeters for ciscoes *(Coregonus sardinella)* taken near Point Barrow, Alaska.

By taking logarithms of the weights in grams (W) and the logarithms of the fork lengths in millimeters (L) to three decimal places, the data of Figure 1 can be put into suitable form for the calculation of the regression constants. The preliminary calculations of the sums of squares and products are given in Table 2. In Table 3 are the sums of squares and products of deviations from the mean log weights (w) and from the mean log lengths (l). From the data of Table 3 it is possible to make comparisons between the two correlations or between the two regressions. Such analyses are necessary, because it would be infeasible to make a simple comparison of average lengths or weights of the two groups inasmuch as the two samples were drawn from populations with somewhat different age (and size) compositions.

Table 2

Calculations of sums, means, sums of squares, and products of log weights in grams (W) and log fork lengths in millimeters (L) for two groups of ciscoes

		Tidal Estuary	Ikroavik Lake		Totals
Number		183	724		907
ΣL		443.475	1722.043		2165.518
Mean L		2.4234	2.3785		2.3876
ΣL^2		1075.080649	4099.826667		5174.907316
$\Sigma L \times W$		995.607788	3787.523122		4783.130910
ΣW		410.393	1586.733		1997.126
Mean W		2.2426	2.1916		2.2019
ΣW^2		924.630833	3526.019985		4450.650818

The correlation coefficients r_E and r_I could be compared by the use of Fisher's Z values as explained by Snedecor (1946, Chapter 7). The difference of the two Z values, 1.23 and 2.19 for the respective estuary and lake correlations, is 0.96. The standard error of the difference is the square root of [1/(183 - 3) + 1/(724 - 3)], or 0.084. For infinite degrees of freedom, a t value of 0.96/0.084 = 11.43 indicates a high degree of statistical significance with a probability of far less than 0.001.

More interesting perhaps are the equations expressing the length-weight relationships of these two groups of fish. The linear equation for all estuary fish is

$$\hat{W} = -4.615049 + 2.829803\, L \qquad (1)$$

where $\hat{W}$ is the estimated log of the weight in grams for any given L, the log of the fork length in millimeters. For all Ikroavik Lake fish, the linear logarithmic relationship is

$$\hat{W} = -5.962332 + 3.428173\, L. \qquad (2)$$

The two equations in logarithmic form are plotted in Figure 2 as solid lines. The mean log weight and mean log fork length for each group is denoted by a cross. These means correspond to geometric means of 265 millimeters and 175 grams for the fish from the estuary and 239 millimeters and 156 grams for the lake fish.

An elegant comparison of these two regressions is possible by the analysis of covariance technique. [See any standard statistics textbook such as Snedecor (1946) or Kendall (1948) for an explanation of the technique.]

:e the age and length compositions of the two groups of data differ, it iesirable to make "adjusted" log weight comparisons by taking into ac- nt the differences in mean log lengths. The appropriate statistical t for this comparison is made by comparing the mean square correspond- to adjusted means (mean square of S_4 in Table 3) to the mean square responding to variation within groups (mean square of $S_1 + S_2$). The alue for 1 and 904 degrees of freedom is 1.378721/0.004125 = 334 which nighly significant (probability less than 0.001). Thus the differences

Table 3

Data for analysis of covariance of log weight and log length data for ciscoes from two localities

Source of Variation	DF	Sums of Squares and Products Σl^2	Σw^2	Σlw	Regressions	Correlations
thin estuary (E)	182	0.380782	4.289770	1.077538	b_E=2.829803	r_E=0.843096
thin lake (I)	723	3.925985	48.503945	13.458957	b_I=3.428173	r_I=0.975323
thin locations	905	4.306767	52.793715	14.536495	b_a=3.375269	-
ween locations	1	0.293814	0.379418	0.333884	b_m=1.136379	-
tal	906	4.600581	53.173133	14.870379	b_o=3.232283	-

		Errors of Estimate	
		Sums of Squares	Mean Squares
thin estuary	181	1.240550	0.006854
thin lake	722	2.364308	0.003275
viations from regressions b_E and b_I	903	S_1 = 3.604858	0.003992
fferences between b_E and b_I	1	S_2 = 0.124284	0.124284
viations from b_a	904	$S_1 + S_2$ = 3.729142	0.004125
viations of cations from b_m	0	S_3 = 0.000000	0.000000
fferences between b_a and b_m	1	S_4 = 1.378721	1.378721
tal	905	$S_1 + S_2 + S_3 + S_4$ = 5.107863	-

l log weights cannot be explained solely on the basis of length dif- erences. To determine whether the two group regressions are the same, the ean square corresponding to S_1 may be compared to the mean square corre- ponding to S_2; *i.e.*, F = 0.124284/0.003992 = 31 (probability less than .001) for 1 and 903 degrees of freedom, respectively. Hence there is no od reason to suppose that the estuary fish and the lake fish have similar ength-weight relationships in spite of the fact that there are several ide departures from the main trends indicated in Figure 1.

Rejection of Measurements: In order to be able to plot length-weight re- ationships with more precision, there might be some temptation to discard he more aberrant values indicated in Figure 1. Discarding the heavier-

than-usual fish from both the estuary and lake collections is especially tempting since a few values are so aberrant that both regression lines (1 and (2) are somewhat displaced from the main bodies of data. At the present time, however, there are no definitive biological characteristics known which would afford a scientifically sound separation of the unusually heavy fish from the remainder. For this reason, *arbitrary* removal of such individuals could be severely criticized. The logarithmic data in question here describe a reasonable, straight line, but a few individual points seem to depart more than would be expected within ordinary statistical limits if the points were distributed normally about a straight line. The aberrancies can be examined statistically by setting up prediction intervals (confidence limits) about the calculated lines, and noting whether the individual aberrancies lie outside definable limits.

The following illustration will serve to explain the procedure of setting up prediction intervals by the method given by Mood (1950), in which the only arbitrariness occurs in setting up the desired intervals.

Consider the aberrantly heavy-bodied lake fish with a fork length of 196 millimeters and a weight of 196 grams; the log of each measurement is 2.292, and the data are plotted as the lower left open circle-over-cross in Figure 1. On a logarithmic basis from (2), the expected log weight for log length of 2.292 would be 1.895. About this point on the line, there would be variability due both to the variability about the regression or slope b_L and to variability about the mean log weight for all the data.

With the data of Tables 2 and 3, the formula of Mood (1950, p. 299) can be used to compute a prediction interval about the estimated log weight of 1.895 corresponding to the given log length of 2.292. The interval is

$$\pm t\, s_{WL} \sqrt{\frac{N}{N-2}\left(\frac{N+1}{N} + \frac{l^2}{\Sigma l^2}\right)}$$

where: t is taken from Student's t table at the desired level of significance for 722 degrees of freedom; s_{WL} is the standard error of estimate ($\sqrt{0.003275} = 0.0573$); N equals 724; l is the difference between 2.292 and the mean log length 2.3785 for all the lake data; and Σl^2 is the sum of squares of the differences of the individual log lengths from the mean log length. If t is chosen at the level of probability of 0.001, the interval from the above formula becomes ±0.190, or with respect to the estimated log weight 1.895, the interval 2.085 to 1.705 should (except for one chance in a thousand) contain all values of normally distributed log weights about the point on the line where the log length equals 2.292. The observed log weight 2.292 lies outside these limits and hence the value might be rejected on the grounds that the length and weight of this particular specimen could occur less than one chance in a thousand.

In a like manner, the other "aberrant" measurements of lake fish can be examined. Only the nine values shown in Figure 1 as open circles-over-crosses can be rejected due to their location outside the 0.999 interval. None of the slender lake forms (open triangles in Figure 1) can be so rejected.

The same procedure was applied to the estuary data, and the 0.999 prediction interval was calculated about equation (1). Only the two values, plotted as open square-over-x's in Figure 1, lie near or outside these limits.

The removal of values lying outside these limits changes the linear relationships of (1) and (2) because in both cases the "rejects" are for heavier-than-normal fish and because the "rejects" are predominantly among the shorter fish. The lake data, after the removal of the nine "rejects"

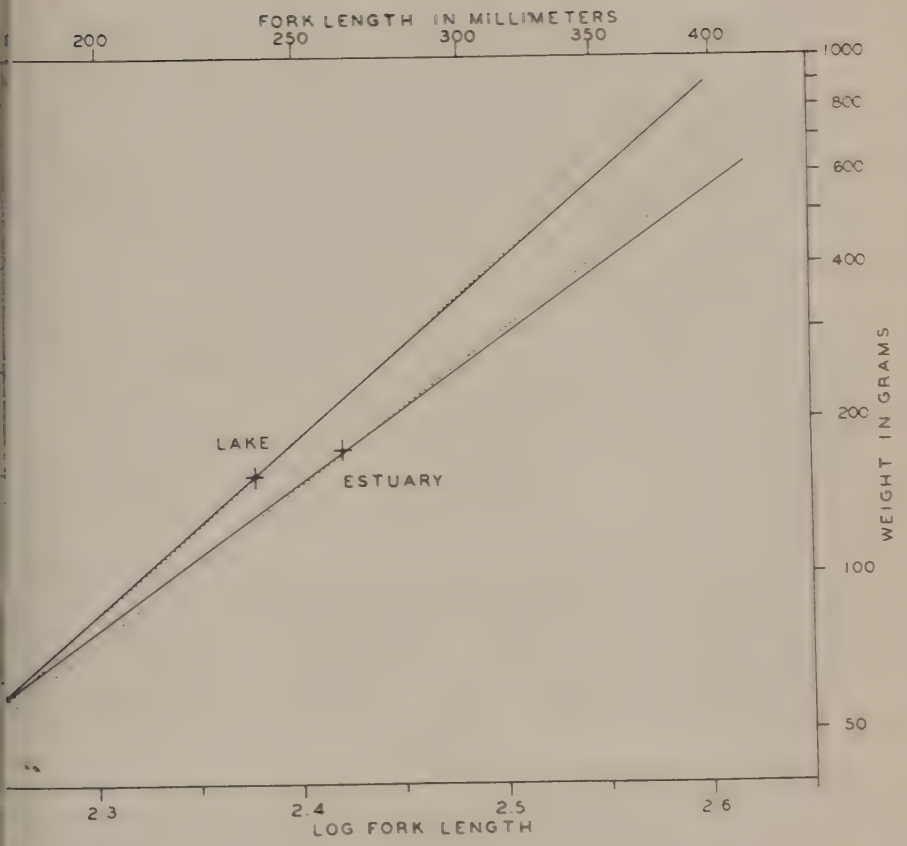

FIG. 2. Logarithmic plots of length-weight relationships of ciscoes from tidal estuary and Ikpavik Lake. Solid lines drawn on the basis of all data with means indicated by crosses. Dotted lines represent relationships after removal of "aberrant" data as explained in text.

can then be reassembled and a new regression may be computed as

$$\hat{W} = -6.023573 + 3.452431\ L \qquad (3$$

which may be compared with (2). The revised regression for the estuary data is

$$\hat{W} = -4.954209 + 2.968412\ L \qquad (4.$$

which may be compared with (1). These two lines are plotted in Figure 2 as dotted lines near the respective solid lines for all the data.

An analysis of covariance made *after* the elimination of the eleven values indicated that the log weight-log length regressions of the lake and estuary data are still different at high levels of statistical significance (probabilities less than 0.001) for both the test of difference of adjusted means and the test of difference in regressions.

Differences Among Ikroavik Lake Ciscoes: In order to evaluate the existence and possible significance of any differences among the three growth types of ciscoes from Ikroavik Lake, the 724 fish were subdivided into 57 "fresh-water" ("F") types, 113 "X" types, and 34 "marine" ("M") types for an analysis of length-weight relationships. The three types were determined by Conen (1954) on the basis of scale structure and the principal environment where fish were believed to have lived.

For this group of fish there were nine "rejects" as explained in the previous section. Three of the rejects had scales of the "F" type and six had scales of the "X" type; none of the relatively slender fish having "M" type scales could be rejected. Among the 681 "F" and "X" types, 0.16 were of the "X" type. From Clopper-Pearson tables of binomial confidence belts (Clopper & Pearson, 1934), the 0.95 limits of this ratio would be approximately 0.13 to 0.19. Yet on the basis of 0.67 "X" types among the nine unusually heavy-bodied rejects, the 0.95 confidence limits would be approximately 0.29 to 0.93. In a preliminary way, at least, this information would suggest that the "X" types of fish possessed an unusually high propensity for "corpulence".

An analysis of covariance of the logarithmic length-weight relationship may be made for these three lake fish groups by utilizing the data summarized in Tables 4 and 5. For a test of adjusted mean log weights, taking into account the different mean log lengths, the appropriate test is $F = 0.026456/0.002197 = 12.04$ for 2 and 711 degrees of freedom - a highly significant value (probability less than 0.001). In other words, the differences among the mean log weights are to be considered real and not al-

Table 4

Calculations of sums, means, sums of squares, and products of log weight in grams (W) and log fork lengths in millimeters (L) for three growth types of Ikroavik Lake ciscoes

	"Marine" Type	"X" Type	"Fresh-water" Type	Totals
Number	34	107	574	715
ΣL	82.699	254.417	1363.811	1700.927
Mean L	2.4323	2.3777	2.3760	2.3789
ΣL^2	201.299763	605.161207	3243.810167	4050.271137
ΣLW	195.255808	561.518919	2980.850361	3737.625088
ΣW	80.086	235.846	1249.547	1565.479
Mean W	2.3782	2.2042	2.1769	2.1895
ΣW^2	190.151172	522.316404	2763.264729	3475.732305

ether due to differences in the mean log lengths of the three types of ı. The three regressions may also be tested for similarities by use of test, $F = 0.015631/0.002160 = 7.24$ for 2 and 709 degrees of freedom. is F value is highly significant at a probability level of about 0.001, ın means that the three regressions plotted in Figure 3 cannot be repre- ted by a common regression line. Thus the log weight-log length re- ionships reflect real differences among these three growth types.

Table 5

ata for analysis of covariance of log weights and log fork lengths for three types of ciscoes in Ikroavik Lake

Source of Variation	Degrees of Freedom	Sums of Squares and Products Σl^2	Σw^2	Σlw	Regressions
hin "M"	33	0.149039	1.510954	0.460746	$b_M = 3.091447$
hin "X"	106	0.226535	2.472145	0.741051	$b_X = 3.271243$
hin "F"	573	3.426119	43.111932	11.954989	$b_F = 3.489368$
hin groups	712	3.801693	47.095031	13.156786	$b_a = 3.460770$
ng groups	2	0.102088	1.050561	0.320750	$b_m = 3.141897$
tal	714	3.903781	48.145592	13.477536	$b_o = 3.452431$

		Errors of Estimate	
		Sums of Squares	Mean Squares
viations from near regressions thin growth types	709	$S_1 = 1.531149$	0.002160
fferences ong regressions	2	$S_2 = 0.031262$	0.015631
viations within owth type groups om regression b_a	711	$S_1 + S_2 = 1.562411$	0.002197
viations between owth type groups om regression b_m	1	$S_3 = 0.042797$	0.042797
fferences be- ween b_a and b_m	1	$S_4 = 0.010116$	0.010116
viations among owth types for sting significance "adjusted" means	2	$S_3 + S_4 = 0.052913$	0.026456
tal deviation from gression b_o	713	$S_1 + S_2 + S_3 + S_4 = 1.615324$	-

The regressions in Figure 3 indicate that the "fresh-water" type ex- eriences the greatest increase in weight with increasing length while the east increase in weight with increasing length occurs among the "marine" ypes; in these respects the "X" types are intermediate.

By omitting the six aberrantly heavy "X" types and the three aberrantly heavy "F" types, the slopes of the two lines are increased since the rejected values apply mostly to shorter fish. The effect of removing the three "F" rejects is to increase the slope of the regression line from 3.481578 to only 3.489368, but the effect of removing the six "X" rejects increases the slope considerably from 3.029218 to 3.271243. However, an analysis of covariance of all the lake data (not given here) indicates that there were very high degrees of statistical significance both for the differences among the adjusted means and for the differences among the three regressions.

Discussion

As the Barrow Eskimo has known for generations, the ciscoes from Ikroavik Lake tend to be somewhat heavier-bodied and much fatter than those from the brackish-to-marine Elson Lagoon waters. The quantitative measurement of these differences is rather difficult, however, and many precautions must be taken when collections from the two localities are compared.

The chi-square technique for the comparison of the length-frequency distributions of catches from the two localities (Table 1) is probably valid in the light of the differences in the length-weight relations of the two groups. Such a "rough-and-ready" length-frequency comparison for distinguishing differences in body forms could be made only if identical gill net mesh sizes were employed. Even then the time and location of collections plus behavior differences among fish in the same body of water could combine to produce effects confounded with real differences in body form according to observations made on closely related species by Hile (1936), Van Oosten and Hile (1949), and Kennedy (1953b). In this connection, it should be noted that any type of gill net, or other types of gear, are apt to "fish" differently in different types of environment so that fish size selection could be quite variable.

Nevertheless, the relation of weight to length was different for the two collections, independently of any size selection by the seine or the various sizes of gill nets and independently of any differences in sex or gonadal maturity. The regressions of weight on length for fish taken by different gear from the same locality were essentially similar for fish longer than 180 millimeters. Seasonal differences did not appear in separate weight-on-length regressions for estuary fish collected in 1951 by Wilimovsky and those collected there in 1952. A preliminary analysis of covariance of these variables for fish taken with the 2-inch stretched mesh gill net in both the estuary and the lake during July and August, 1952, showed the two groups to be different at a time when neither group contained ripe fish. Regressions made when a greater proportion of the lake fish were ripe later in the season did not differ appreciably from the regressions of the lake fish earlier in the season. Insufficient fish were sexed until the end of the summer (the time of greatest gonadal maturity), and at that time there were no major differences in length-weight relationships between males and females. Kennedy (1953a) has also noted that the two sexes of *Coregonus artedi* in Great Bear Lake differed very little morphologically, although a morphological difference affecting both sexes did occur in collections from different environments in that lake. In Great Slave Lake, Kennedy (1953b) found no apparent differences in length-weight relationships for the two sexes of the whitefish, *Coregonus clupeaformis*. Sex, gonadal maturity, and age differences are, however, sometimes more obviously reflected in the morphology of coregonid species in temperate and subarctic waters as Hile (1936), Van Oosten and Hile (1949), Svärdson (1951), and many others have shown. Fish smaller than those in this study

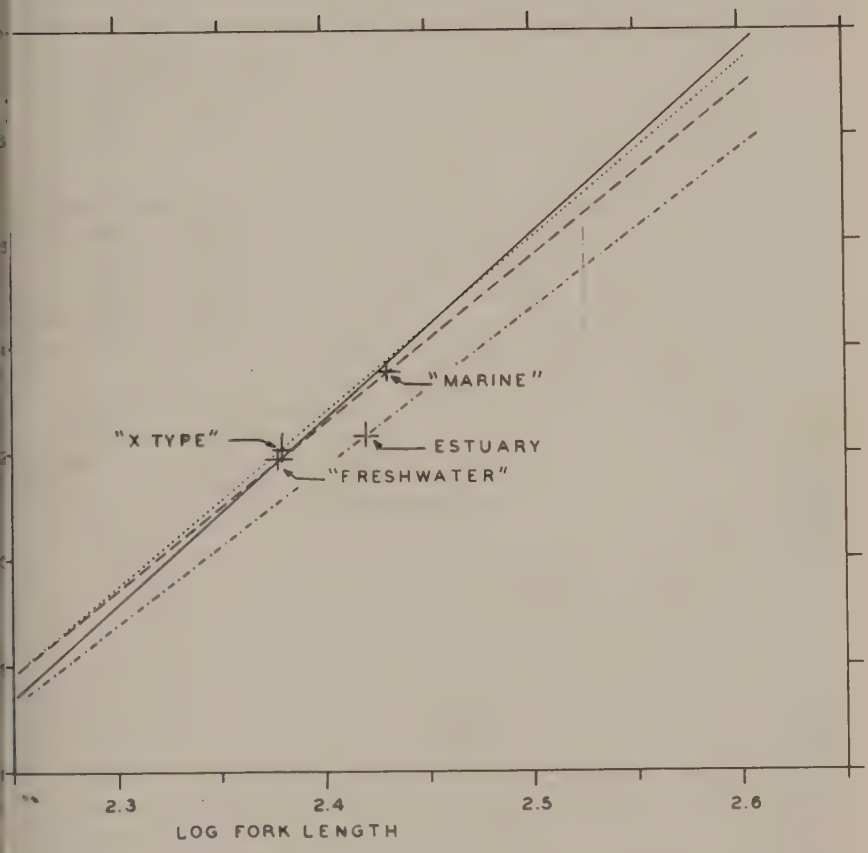

FIG. 3. Logaritnms of weignts in grams plotted against logaritnms of rk lengtns in millimeters for three types of Ikroavik Lake ciscoes, and r tidal estuary fisn. Relationsnips are snown for fisn witn "fresn-water" pe scales, "X" type scales, and "marine" type scales by solid, dotted, d broken lines, respectively; relationsnip for fish from estuary indicated dot-dasn line; mean log lengtns and log weignts indicated by crosses.

may well have different length-weight regressions, but adequate data o this point are not available.

It is interesting to note that the length-weight regressions for the es tuary and lake fish (Figures 1 and 2) tend to diverge from an approximat length of 180 millimeters and from a weight of around 55 to 59 grams. A this and smaller sizes the fish would be three or four years old or younger and most all would presumably be confined to fresh waters.

In general, then, there is little reason to suspect that either th method or season of collection, sex, or gonadal maturity would affect th comparisons of lengths and weights for fish longer than 180 millimeters, s that the different body forms of the estuary and the lake specimens are no due simply to circumstances of collection. And because the lake fish are on the average, deeper-bodied than the estuary forms for any given lengt above 180 millimeters, it may be assumed that the chi-square analysis o length-frequency distributions as described above would be fully satisfac tory as a field procedure to separate populations on the basis of bod depths of individual fish.

Most noticeable among the data of Figure 1 are the unusually deep-bodie fish from both the estuary and the lake and the unusually slender fish fro the lake. In several of the more comprehensive studies on coregonids fro temperate waters, the authors have not mentioned heavy-bodied aberran forms in their collections. Ordinarily, figures of published length-weigh data for coregonids and many other species of fish show in a general wa that the relationships are linear in logarithmic form with the individua observations "normally" distributed about the best straight lines. Two o the unusually heavy lake fish plotted in Figure 1 had obvious spinal de formities, and it is possible that some other "aberrancies" were the resul of measuring, weighing, or recording mistakes, even though all measurement and weights were made personally with great care. The unusual slendernes of some of the lake fish could be explained most likely by parasitism, an there is little reason to question the validity of these data. For *all* th fish whose fork lengths were 180 millimeters and over, equations (1) an (2) should adequately describe the *average* fish in the two samples.

If more data had been available, it would have been possible to deter mine the average (mean) and the median log weights for any given smal grouping of log lengths so that the statistical nature of the individua log-weight distributions could be examined. It would then be possible t process the individual log-weight distributions for "outliers" by th methods such as described by Dixon (1953) for cases where mean and media log weights showed a wide discrepancy. Unfortunately, even the large lak collection, which consisted of around one-tenth of the total estimate population (Wohlschlag, 1953), would be rather inadequate for this type o examination.

If the log-weight data of these ciscoes should for any reason be ex pected to be normally distributed about the logarithmic length-weight re gression, as is true for many fish species, then rejections of extremel heavy or light fish would be theoretically possible on the grounds tha such fish might not "belong" to the population in question. When predic tion intervals designed to include 99.9% of all data are set up and th several values shown in Figure 1 lie outside the limits, there is imme diately some suspicion that the aberrant fish are the result of som growth or developmental peculiarity. With the inclusion of several hundr lake fish shorter than 180 millimeters (not shown in Figure 1) it seeme obvious that the unusually "corpulent" forms were not only relativel more numerous, but were also more widely aberrant as the lengths decrease this would probably have been true had there been some method of correc ting for the net selectivity in retaining only the more heavy-bodied for among the very small fish. These observations tend to suggest that th

bodied form was determined early in the lives of such fish, and that magnitude and proportions of such fish declined (possibly because of tive mortality) as the fish grew larger. Martin (1949) has reviewed problem critically and has discussed the possibility of temperature ng embryological development and the possibility of diet of very small as important influences on the regulation of body form during the ear- et growth stanzas. Martin also has noted that there is the possibility higher mortality among fish which do not conform to a normal relative- ctn pattern. Perhaps the latter possibility is also suggested by the that no unusually slender forms occurred among the estuary fish, and these fish and the heavily parasitized slender lake forms represent a r limit of slenderness consistent with survival.

Although the unusually slender lake fish can be accounted for by para- sm acquired in the lake, there seem to be good reasons to suspect that origin of the heavy-bodied fish is in an environment unlike that of Ik- ik Lake or that from which the majority of the estuary fish originally . For these reasons, there is some suggestion of a biological justifi- ion for "rejection" of some of the more extreme forms which lie outside ratner severe, though arbitrary, 99.9% prediction intervals. With the lake and two estuary "rejects" excluded, equations (3) and (4), as n by dotted lines in Figure 2, follow much more closely the main body ata, inasmuch as the slopes are increased by the removal of aberrant -weight values which have lengths near or less than the mean log lengths. In any event the distinction between estuary and lake fish with respect he relations between lengths and weights is clear from the analyses of ariance, whether or not the aberrant forms are removed. The clarity of quantitative distinction is enhanced not only by the qualitative differ- es in abdominal fat deposits and general appearance of the two groups but o by the fact that Cohen (1954) discovered that all estuary fish had a gle characteristic scale-growth pattern found among only a few lake fish. Briefly, Conen (1954) discovered that all the estuary fish and about e per cent of the lake ciscoes had scales which exhibited regular annuli circuli much like most of those depicted in figures of coregonid scales ilished by many authors; Conen designated these as "marine" ("M") type les. About 79 per cent of the lake fish had scales whose annuli were e, clear, concentric bands, presumably associated with the cessation of wth during the long period of confinement under the ice cover; these h were called "fresh-water" ("F") types. About 16 per cent of the lake h had scales with crinkly, irregular circuli and were without the wide, ar, annular bands except those formed one or two years prior to the time collection; these fish were called "X" types and Conen suggested that ir origin might be outside the lake.

A comparison of the length-weight relationships among the Ikroavik Lake sh having these three types of scales is most revealing in regard to the ssible causes of growth differences. Conen (1954) analyzed the data by mparing the age-length plots of the estuary fish with "M" type scales, e lake fish with "F" type scales, and the lake fish with "X" type scales. s results showed that the "F" type fish were longer than the estuary fish the "X" types at any given age, and that the change in length with age ll off most rapidly for the "X" types from the lake. Of course, it is ssible that conclusions from this type of analysis could have been in er- r because the choice of only three scale types may have been too arbi- ary, because the types of circuli on the scales may have had no real re- tion to growth, and because there were very few older fish upon which to se age-length relationships. For these reasons, the analysis of covariance log-weight on log-length regressions for the three types from Ikroavik ke was used to detect gross differences in body form not obvious from gth measurements alone. As a result of the length-weight analysis of

lake and estuary fish, it became rather clear that the weight of a fres fish in relation to its length could be valuable as a systematic characte: istic reflecting body depth. Somewhat akin to the above are relationship among other body proportions. For example, it has been recognized by mar workers that plump, rapidly growing coregonids and salmonids ordinarily have relatively shorter and smaller heads than slender, slower growing mem bers of these groups exhibit.

An analysis of covariance of the three lake types which included th nine aberrant values also indicated a high degree of statistical signifi cance between both the adjusted means and the regressions themselves, bu the disturbing effect of the six "X" type "rejects" on decreasing the re gression is very great. The fact that six out of nine "rejects" had "X type scales compared to a proportion of about 0.16 "X" types among all ou the "M" types in the lake might be regarded as evidence suggesting tha whatever contributes to unusual "corpulence" influences the "X" more tha the "F" types.

Among the scales of the more normally shaped fish from the lake, mos of the "X" types had the terminal one or two years of growth characterize by the wide, clear, concentric annuli which prevailed over all the annul of the "F" types. There was no good way, however, to draw sharp distinc tions among "M", "X", and "F" annuli representing about the first two yea of scale growth (about three years of fish growth, since the fish ar around one year old before scales are formed). Presumably this would in dicate that fish growth during the first two or three years was normall fairly uniform, and might suggest that major growth differences would b associated with environmental influences operating more strongly upon th older fish. This is indeed suggested by the divergence of the regressior for estuary fish and lake fish in Figure 2. If the broad, clear circul are characteristic of Ikroavik Lake growth, the "M" type scales on 34 o the lake specimens provide evidence that these few fish had recently en tered the lake, in spite of the fact that traps in the outlet of the la failed to capture a single immigrant (or emigrant) all summer in 1952. B cause the degree of increasing weight with length is greatest for the "F types, intermediate for the "X" types, and least for the "M" types of la fish, the interpretation of length of lake residence based upon the fra tion of broad, clear annuli on any given scale seems quite reasonable. I terestingly enough, an analysis of covariance of the log lengths and lo weights of the estuary fish and the "M" types from the lake without th "rejects" reveals very clearly that the adjusted log weights of the tw groups are different with a high degree of statistical significance. Ho ever, the two regressions, 2.968412 for the estuary fish and 3.091447 fo the "M" type lake fish, are not statistically different, which means sim ply that all sizes of estuary type fish, if they did enter the lake, be came uniformly heavier, and not relatively heavier, with increasing lengt as is the case for the "F" and "X" types in the lake.

The regressions for "M" type lake fish and the estuary fish (equation are illustrated in Figure 3. All these relationships would tend to mak any assumption of existence of important genetic differences among th various types of ciscoes from the two major types of environments rathe incomprehensible. Accordingly, the causes of variability of growth an form of this species might logically be sought among the rather diver environmental conditions present in the Arctic.

Since all groups of ciscoes contained both males and females and a proximately the same proportions of fish from different year-classes, di ferences in length-weight relationships are over and above sexual and yea class variability. Morphological differences among the groups may, how ever, be related to several important environmental characteristic: Individual environments of the Arctic Ocean, Elson Lagoon and tidal e

ies, fresh-water Ikroavik Lake and its outlet, and other lake and am systems of the arctic slopes would be expected to differ consi- ply with respect to salinity, temperature, light, space (*lebensraum*), food supply, all of which could influence development and growth.

The most obvious difference in the environments is salinity, which es from about five to 34 parts per thousand in the Arctic Ocean in the er (Wilimovsky, 1953) and perhaps even more in Elson Lagoon. Ikroavik has a very low mineral content among the fresh waters of the area Prescott, 1953). Among the anadromous arctic salmonids and coregonids amounts of growth and fat accumulation in the marine and brackish habi- are apparently the exact opposite for the two families. Knowledge of crine control of metabolism in fish has been established and the sub- has been reviewed recently by Fontaine (1953). It is quite possible metabolism and thyroid regulation are different for the two families. some salmonids it is known that metabolism and thyroid development dif- from fresh to marine waters and that this variation could be related the iodine accumulation in the waters (Robertson & Chaney, 1953), these factors and their influence on arctic coregonids have not been ied. It is also possible that metabolism and physical activity neces- y for biological maintenance of a fish may vary from marine to fresh ers, and from flowing to standing waters. Whatever the effect that ine environment has on growth of ciscoes, it may occur after the fish several years old, since there has been no evidence of one- or two- r-old fish in the marine coastal area. Presumably all young ciscoes restricted to fresh-water environments.

The temperature variation in waters of the Barrow area is greater than int be supposed. Seasonal lake temperature data have been given by ita and Edmondson (1953) and Wohlschlag (1953), and comparable data for Arctic Ocean have been given by Wilimovsky (1953). Lakes are open for to three months; streams are open and actively flowing for around four ths; the ocean, depending upon wind, currents, and position of the pack e, is open from a few weeks to several months; and the coastal lagoons d other protected inshore waters are open about as long as the lakes. In e shallow inland lakes, temperatures average around two degrees Centigrade gher than in marine and brackish waters, with maxima around 12° to 14° C. the shallow Ikroavik Lake outlet, temperatures as high as 25° C. were corded during a period of sunshine in June; this recording was made sev- al hundred yards below the lake with its six-foot ice cover. The ciscoes d other Barrow coregonids experience all their annual growth in two or ree summer months, according to Cohen (1954). Kennedy (1953b) has shown at about half of the annual growth of *Coregonus clupeaformis* occurs dur- g the first two weeks of August in Great Slave Lake, which is ice-free r about three months. Paradoxically, in the unstratified waters of the allow arctic lakes, summer temperatures for about two weeks would be con- derably higher than the temperatures of hypolimnetic coregonid habitats the deeper lakes in temperate regions. Effects of temperature on *Core- nus clupeaformis* larval development have been summarized by Price (1940), o noted that at high temperatures there was a greater incidence of em- yological abnormality, but as yet it is unknown whether temperatures at rval stages of *Coregonus sardinella* actually influence the growth and rm of the fish in later life. In lakes the temperatures during develop- ntal stages would be near one degree Centigrade, since the species spawns ortly before ice formation and hatches before ice break-up. Somewhat gher temperatures may prevail in streams, either at time of spawning in te summer or at time of post-larval stages in the spring. Cohen (1954) s investigated the relationship between the calculated average annual owth increments from scale measurements, and the average May-September rrow air temperatures for estuary fish and for the "F" and "X" types from

Ikroavik Lake. Only the "X" type fish seemed to show any correlation between air temperature and growth. This correlation and the higher incidence of abnormal forms among the "X" types (possibly due to larval development at high temperatures) provide indirect evidence that the "X" type may have originated in streams which probably reflect air temperatures more closely, and have greater temperature variations, than other arctic waters.

Closely allied to temperature fluctuations are fluctuations in *lebensraum* as waters freeze and thaw. Large areas of shallow Elson Lagoon freeze and presumably the fish either go to deeper and more saline marine waters or migrate upstream in the late summer. In shallow Ikroavik Lake, with a rather uniform depth, it is estimated that upon freezing the volume is reduced to about 10 per cent of the summer maximum. Reduction in volume of the smaller streams would be even more complete. Comparable habitat reductions would occur in all of the waters of the northern arctic Alaskan slope. Virtually nothing is known of the influence of spatial restriction on the life history of *C. sardinella*, though it may be presumed that competition for food might exist.

Transparency of waters can also have a great, if indirect, effect on fish growth. With increasing turbidity, feeding by sight would be impaired and photosynthetic activity and forage production would be lowered. In addition it is possible that light could influence embryological development and body form, as has been discussed by McHugh (1954). Streams and coastal waters are almost continuously highly turbid in the Arctic; lakes tend to be somewhat clearer, at least during periods of calm. Variability in the quantity of penetrating light would also be great, depending upon length of the ice-free season and amount of snow cover on ice. Among fresh waters, the streams would probably be more variable in this respect than lakes.

The abundance and kinds of zoöplankton and the efficiency of its utilization by *Coregonus sardinella* are almost totally unknown for these environments. There is a wide diversity of forms of zoöplankton from the marine to fresh-water areas which was reflected in the types of food found in the stomachs of fish from these localities, although any quantitative difference in amounts of zoöplankton could not be related to the fullness of stomachs of the various groups of fish because most all stomachs were uniformly filled. Recently, field transplantation studies by Svärdson (1951) and others have revealed that the body form of coregonids, their year-class strengths, and their ageing depend upon food supply. Physiological aspects of growth and body form as related to food have been reviewed in detail by Martin (1949).

There are, then, some major diversities among temperatures, fluctuations in habitat volume, light, and no doubt foods and feeding activities among fish from various arctic Alaskan fish environments. These factors, affecting both embryological and later development in fresh waters would likely be most variable in the streams. Growth and metabolism among the older fish are apparently grossly different for fish in marine and brackish coastal waters and in fresh waters, but there is little evidence at this time to suggest what the causes of these differences are.

Conclusions

A study of the growth characteristics of the cisco, *Coregonus sardinella*, taken from a marine coastal estuary and from fresh-water Ikroavik Lake in the vicinity of Point Barrow, Alaska, revealed major growth differences between fish from the two environments and among the fish within the lake. A fairly good linear representation of length-weight relationships may be obtained by plotting the log weights in grams (W) against the log fork lengths in millimeters (L) for fish whose fork lengths are 180 millimeters or more.

Lake fish had very large amounts of viscerally accumulated fat, the estuary fish did not.

For all the estuary fish the logarithmic length-weight relationship is

$$\hat{W} = -4.615049 + 2.829803\ L.$$

For all lake fish, the comparable relationship is

$$\hat{W} = -5.962332 + 3.428173\ L.$$

. Not only are the lake fish heavier, but length for length they are gressively heavier with a high degree of statistical significance.

. Differences between the relative "corpulence" of estuary and lake also can be detected readily by a chi-square analysis of frequencies arious lengths of fish taken from the two environments by a gill net of en mesh size. The utility of this procedure for field studies is aluated.

Among both estuary and lake collections there appeared a few unusually y-bodied fish which could possibly be "rejected" on statistical grounds. use several of these fish had obvious spinal (embryological) deformes, the possibility that their corpulent form arose as the result of ronmental conditions is discussed. It is tentatively concluded that ronmental conditions could be responsible for such major aberrancies.

5. If two such aberrant fish are removed from the estuary collection logarithmic length-weight relation is

$$\hat{W} = -4.954209 + 2.968412\ L.$$

7. If nine such aberrant fish are removed from the lake collection the parable regression is

$$\hat{W} = -6.023573 + 3.452431\ L.$$

8. Results in 6. and 7. do not affect the conclusion of length-weight ferences between lake and estuary fish.

The length-weight relationships of Ikroavik Lake ciscoes were investiged with respect to three scale-growth types discovered by Cohen (1954). Fresh-water", "marine", and unknown ("X") types of environments were supedly associated with these scale types. For lake fish having these ee forms of scales, the logarithmic relationships of weights to lengths vealed:

9. That there is a great difference among the mean log weights and log ngths for these three groups, and

10. That the three regressions differ in that there is the most pronced increase in weight with length for the fresh-water types, an intermediate increase for the "X" types, and the least increase for the marine pes, and

11. That these three regressions bear resemblance to each other more osely than they do to the regression for the estuary fish.

12. The "marine" type fish in the lake are significantly and uniformly avier than the estuary fish, but they are not relatively heavier with creasing lengths.

13. A disproportionately great number of the aberrantly "corpulent" ke fish possessed the "X" type of scale.

14. The possible causes of differences in body form among the ciscoes e discussed with reference to the environmental differences which exist ong lakes, streams, and marine or brackish coastal waters in the Arctic. jor environmental differences exist for salinity, temperature, space,

light, and food factors, which could affect either or both embryological development and later growth. For most of these factors, except salinity, the stream environments would be expected to be the most variable.

LITERATURE CITED

CLOPPER, C. J., and E. S. PEARSON
1934 The use of confidence or fiducial limits illustrated in the case of the binomial. Biometrika, vol. 26, pts. 3-4, pp. 404-413.

COHEN, Daniel M.
1954 Age and growth studies on two species of whitefish from Point Barrow, Alaska. Stanford Ichth. Bull., vol. 4, no. 3, pp. 168-187, figs. 1-15.

COMITA, G. W., and W. T. EDMONDSON
1953 Some aspects of the limnology of an arctic lake. *In*: Current Biological Research in the Alaskan Arctic, Ira L. Wiggins, ed. Stanford Univ. Publs., Univ. Ser., Biol. Sci., vol. 11, no. 1, pp. 7-13.

DIXON, W. J.
1953 Processing data for outliers. Biometrics, vol. 9, no. 1, pp. 74-89.

DUNBAR, M. J., and H. H. HILDEBRAND
1952 Contributions to the study of the fishes of Ungava Bay. Journ. Fis. Res. Bd. Canada, vol. 9, no. 2, pp. 83-128.

DYMOND, John R.
1943 The coregonine fishes of northwestern Canada. Trans. Royal Canadian Inst., vol. 24, no. 2, pp. 171-231.

FONTAINE, M.
1953 La fonction hypophyso-thyroïdienne des poissons dans ses rapports avec leur morphologie et leur comportement. Journ. du Conseil, vol. 19, no. 1, pp. 23-38.

HILE, Ralph
1936 Age and growth of the cisco, *Leucichthys artedi* (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Bull. U. S. Bur. Fish., vol. 48, pp. 211-317.

JÄRVI, T. H.
1950 Die Kleinmaränenbestände in ihren Beziehungen zu der Umwelt (*Coregonus albula* L.). Acta Zoologica Fennica (Finlands Fiskerier Bd. 20), vol. 61; 116 pp.

KENDALL, Maurice G.
1948 The advanced theory of statistics. Ed. 2, vol. 2, vii+521 pp. Charles Griffin & Co., London.

KENNEDY, W. A.
1953a The morphometry of the coregonine fishes of Great Bear Lake, N.W.T. Journ. Fish. Res. Bd. Canada, vol. 10, no. 1, pp. 51-61.
1953b Growth, maturity, fecundity and mortality in the relatively unexploited whitefish, *Coregonus clupeaformis*, of Great Slave Lake. Journ. Fish. Res. Bd. Canada, vol. 10, no. 7, pp. 413-441.

MARTIN, W. R.
1949 Mechanics of environmental control of body form in fishes. Univ. Toronto Studies, Biol. Ser., no. 58 (Publs. Ontario Fisher. Res. Lab., no. 70), 75 pp., 13 tabs.

McHUGH, J. L.
1954 The influence of light on the number of vertebrae in the grunion, *Leuresthes tenuis*. Copeia, 1954, no. 1, pp. 23-25.

MOOD, Alexander M.
1950 Introduction to the theory of statistics. xiii+433 pp. McGraw-Hill Book Co., New York.

COTT, G. W.
53 Preliminary notes on the ecology of freshwater algae of the arctic slope, Alaska, with descriptions of some new species. Amer. Midland Nat., vol. 50, no. 2, pp. 463-473.

E, John W.
40 Time-temperature relations in the incubation of the whitefish *Coregonus clupeaformis* (Mitchill). Journ. Gen. Physiol., vol. 23, no. 4, pp. 449-468.

RTSON, O. H., and Albert L. CHANEY
53 Thyroid hyperplasia and tissue iodine content in spawning rainbow trout: a comparative study of Lake Michigan and California sea-run trout. Physiol. Zoöl., vol. 26, no. 4, pp. 328-340.

ECOR, George W.
46 Statistical methods applied to experiments in agriculture and biology. Ed. 4, xvi+485 pp. Iowa State College Press, Ames, Iowa.

RDSON, G.
51 The coregonid problem. III. Whitefish from the Baltic successfully introduced into fresh waters in the north of Sweden. Institute of Freshwater Research, Drottningholm, Report No. 32 (Annual Report for the Year 1950 and Short Papers), pp. 79-125.

OOSTEN, John, and Ralph HILE
49 Age and growth of the lake whitefish, *Coregonus clupeaformis* (Mitchill) in Lake Erie. Trans. Amer. Fish. Soc. for 1947, vol. 77, pp. 178-249.

IMOVSKY, Norman J.
53 Inshore temperature and salinity data during open water periods, Point Barrow, Alaska, 1951-1953. Technical Report IV, Contract N6onr-25136, NR307 204, U. S. Office of Naval Research, 14 pp., multilithed.

LSCHLAG, Donald E.
53 Some characteristics of the fish populations in an arctic Alaskan lake. *In*: Current Biological Research in the Alaskan Arctic, Ira L. Wiggins, ed. Stanford Univ. Publs., Univ. Ser., Biol. Sci., vol. 11, no. 1, pp. 19-29.

Mortality rates of whitefish in an arctic lake. Ecology. (In press.)